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RAIL TRANSPORTATION OF COAL IN WESTERN CANADA

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May 1988

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The contents of this report reflect the views of the author and the mine representatives interviewed and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

Un sommaire en français de ce rapport est inclus après la table des matières.

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17. Abstract

Problems currently being encountered in the rail transportation of coal by five Canadian coal producers are identified. Current state-of-the-art in rail transportation technology is reviewed under the following headings: locomotives; freight cars; unit trains; remote locomotive consists; train control systems; railway electrification; wayside surveillance of trains; computer technology; track. Ongoing technological developments and research in the following areas are summarized: radial axle trucks; reduction in freight car weight; reduction of train resistance; AC traction; rail profile grinding; concrete track ties; rear-of-train telemetry; locomotive event recorders; advanced train control systems.

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17. Résumé

La recherche a cerné les problèmes inhérents au transport ferroviaire du charbon, du point de vue de cinq sociétés productrices canadiennes, et fait un tour d'horizon de l'état actuel des techniques ferroviaires dans les neuf secteurs suivants: matériel de traction, wagons, trains-blocs, traction répartie dans la rame, systèmes de commande, électrification, surveillance au sol des trains, informatisation et voie ferrée. Le rapport donne un aperçu des travaux de R&D en cours dans les secteurs suivants: bogies à essieux orientables, allégement des wagons, réduction de la résistance à la marche, traction en alternatif, reprofilage des rails, traverses de béton, surveillance en queue de train, enregistreurs marqueurs d'événements et systèmes avancés de commande des trains.

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SUMMARY

1. INTRODUCTION AND OBJECTIVES

The major producing Canadian coal mines and reserves lie largely in eastern British Columbia, mid and western Alberta and southern Saskatchewan. The product must therefore be moved by rail over long distances and the cost and quality of the service provided by the railways are therefore of particular interest to the coal producers. Because of the importance of the coal industry to the Canadian economy, that interest is shared by governments at both Federal and Provincial level. On the other hand the railways have a strong interest in the welfare of the coal industry. The 34 million tons of coal they handled in 1986, for example, constituted approximately 19% of all rail shipments and produced $662 million in revenues.

The primary objective of this work was to document the current problems associated with rail shipment of coal in Canada as identified by the mine operators. This was achieved through meetings with representatives of five major coal companies. The second objective was to prepare a description of the current state-of-the-art in rail transportation technology and a summary of ongoing technological development and research.

2. PROBLEMS IDENTIFIED BY MINE REPRESENTATIVES

Overall, the coal companies appear to feel that the railways are doing their best to provide the level of service they require, but rail haul distances are great and the consequent high transport costs are a continuing and major concern of the producers. Other rail-related problems identified by the mine representatives are summarized below.

Delays in Arrival of Empty Trains for Loading

Despite pre-arranged schedules, late arrivals of empty trains for unloading are frequent. If the mine is not operating on a 24-hour basis and the late train arrives when no shift is on duty, the loading crew must be called out

by the mine and overtime rates paid. A stockpiling problem at the mine could result if the silos there are filled before arrival of the train and extra costs at the unloading terminal could occur due to conflict with scheduled unloading times of trains arriving from other mines.

Difficulties With Unloading Cars

The coal cars are rotated at the unloading terminal and the load discharged by gravity. Due to moisture present in the coal when it is loaded, it sometimes freezes during transit and so will not flow out of the car. This is not a serious problem at Thunder Bay where there are thaw sheds, although there is a cost involved.

At the west coast ports frozen loads occur less frequently than at Thunder Bay because of generally higher temperatures encountered en route and shorter trip times. There are no thaw sheds though, and if the load in a car is frozen, unloading can only be accomplished with difficulty. Generally though, it was the feeling of the mine operators that freezing is not of sufficient concern to justify major expenditures to eliminate it.

Even in the absence of freezing, "carry-back" in the order of one ton is experienced with some cars due to non-functioning drain holes in the car and consequent compaction and build-up of the coal around the holes.

Environmental Requirement to Prevent Blow-off of Coal Dust

To prevent blow-off, the top of the load in each car is sprayed with a liquid chemical after loading. The cost of the chemical is approximately $0.10 per ton of coal, but this was said by the mine representatives to be less costly than the use of covers on the cars.

Other Problems Identified

Probably due to blocked or otherwise non-functioning drain holes, some cars placed for loading contain significant amounts of water. Also, there are

sometimes variances in the heights of cars, which delays loading. One mine representative expressed concern that the serving railway would not be able to supply sufficient unit trains if sales continue to grow. The serving railway is already leasing some 300 cars from a railway in the USA. In the case of less-than-unit train movemerts for which the same company uses bottom dump cars, it was said that sufficient cars are not always available.

3. RAIL TECHNOLOGY: STATE-OF-THE-ART

Fundamental changes have taken place within the North American railway system over the past forty years. Early in that period the steam locomotive disappeared from the scene and was replaced with the cleaner and more efficient diesel-electrics. The general-purpose box car has been largely replaced by a variety of special commodity high-capacity vehicles, many of which are operated continuously in 100-car unit trains. The track structure has been greatly strengthened, train control systems have been improved and computer technology now pervades the industry. Canadian railways have frequently led the way in these changes and are recognized world wide as being in the forefront of railway technology.

Locomotives and Cars

The first significant purchases of diesel locomotives for Canadian service occurred in the late 1940's and by 1960 the switch to diesel operation in Canada was complete. The early units were rated at 1000 to 1500 h.p. but new developments came rapidly and by the end of 1985 almost 50% of the units in service were 3000 h.p. or greater. Currently, 3800 h.p. and 4000 h.p. units are being purchased by CN.

Through the development of devices to prevent wheel slip, the effective tractive effort of diesel locomotives on steep grades has been increased by 50% or more. The consequent reduction in horsepower requirement reduces both fuel consumption and locomotive ownership needs. Fuel consumption has also been reduced through the development of improved turbochargers and

various other engine components, including devices to shut down and re-start units in a consist from which the power is temporarily not required.

Equally dramatic changes have occurred to the car fleet on Canadian and American railways. Whereas formerly the box car outnumbered all other cars combined, it now represents only about 40% of the Canadian rail car fleet. The earlier 80-ton capacity gondola and hopper cars used in bulk commodity traffic have been superseded by cars having a capacity of 100 tons or more and the 40-to 50-ton capacity, general-purpose wooden box cars of the past have been replaced by 60-to 80-ton capacity steel vehicles.

With the growth of container/trailer on flat car (COFC/TOFC) traffic, various new flat car designs have emerged consisting of lightweight platforms in lieu of the conventional flat car deck. In some designs the "car" length is extended by connecting several platforms together with semi-permanent drawbars permitting articulation between platforms for negotiating curves, standard couplers being employed only on the outer ends of the end platforms. Frequently, single-axle trucks are employed rather than the usual two-axle truck. New designs also include single stack and double stack types, the double stack being capable of carrying two containers, one above the other.

Unit Trains

Unit trains provide the means to maximize the productivity gains that have been made possible through the increases in car capacity and locomotive power. In a unit train, the cars are kept intact in train sets which shuttle in tightly controlled cycles between points of origin and delivery. Coal, ore, grain, automobiles, containers and trailers are commonly handled in unit trains. Car utilization is high and labour input low with resulting low unit transportation cost.

Dedicated terminals are integral components of unit train services. Typically, in the case of bulk commodities, 100-car trains are automatically loaded and unloaded at the points of origin and destination

respectively. Intermodal terminals utilize high-capacity gantry cranes and fork lift trucks for the loading and unloading of containers and trailers.

Remote Locomotive Consist

An important development over the past two decades has been the use of locomotive units placed in the body of a train and radio-controlled by a locomotive engineer in the consist at the head of the train. This has the following principal advantages:

- reduced drawbar loads, permitting heavier trains to negotiate steep grades
- shorter stopping distances due to faster brake responses
- reduced train shocks and therefore less equipment damage, due to faster and more uniform brake responses.

Train Control Systems

Train Order System

The basic objective of all train control systems is to ensure the safe and efficient movement of rail traffic from origin to destination. The introduction of the telegraph in the 1850's enabled development of the train order system in North America and the abandonment of other less safe and efficient systems. The train order system, (written train orders authorized by a central dispatcher and delivered manually by the station agent to the crew of a train), gives exclusive possession of a specified portion or "block" of the route to a single train. Some low density portions of the Canadian railways are still operated by train order.

Automatic Block Signal (ABS) System

In the 1940's Canadian railways augmented the train order system with the ABS System. In ABS territory, the main line is divided into a series of consecutive segments, or blocks, each one governed by a fixed signal installation. An important feature is that the block signals are automatically controlled by the trains themselves. Presence or absence of a train is determined by an electrical circuit (track circuit), which utilizes the rails as electrical conductors.

In high traffic territories, ABS is an appreciably safer system of train control than is the train order system and train delays are reduced. Although many miles of ABS have been replaced by Centralized Traffic Control, CN and CP together still operate trains by ABS on more than 2600 track miles.

Centralized Traffic Control (CTC) Systems

The first installation of CTC on a Canadian railway was made in 1941. CTC is a system of train operation by signal indication controlled from a central location. It places the control and operation of block signals and switches over an extended territory directly in the hands of the train dispatcher. CTC reduces the number of operators needed to run trains, directs trains entirely by signal indication, operates siding switches and crossovers electrically and automatically informs the dispatcher, by visual and audible indications, of the location of all trains in the territory.

Recent enhancements to CTC systems,resulting from the availability of new microprocessor technology, include varying degrees of computer-aided dispatching. Computer-aided dispatching has been implemented at several major dispatching positions in Canada and incorporate a number of features not normally found on conventional CTC control machines.

A single-track route equipped with CTC can handle approximately the same number of trains as a double track route equipped with ABS. Today Canada's two major railways operate trains by means of CTC on approximately 8000 miles of track.

Manual Block System (MBS)

MBS was introduced on Canadian railways in the 1960's for application where low traffic levels do not warrant ABS or CTC installations. In MBS, radio is utilized rather than written train orders.

Much of the MBS territory has been, or is currently being, enhanced by a Computer Assisted Manual Block System which provides dispatchers with a video monitor to display the territory. Also provided is a much improved

communications console. The system has been implemented on a total of approximately 22,000 route miles in Canada.

Railway Electrification

Although a major study on the electrification of Canadian railways carried out in 1976 established it is technically feasible, neither the operational savings to the railway nor the benefits to the national economy were found to be sufficient to justify conversion of the present system. Subsequent studies, however, resulted in the BCR electrifying their new 82-mile Tumbler Ridge Branch Line at the time of its construction. Completed in 1983 to transport coal from northeastern B.C., it is the only electrified rail freight line in Canada and one of only three in the world having a 50 kV, 60 Hz power supply.

Wayside Surveillance of Trains

The development of equipment over the past 30 years for the wayside surveillance of trains has been a major factor in increasing the safety of train operations.

The principal such device, the hot box detector, detects an overheated bearing on a car through the use of heat-sensitive transducers mounted on each side of the track and placed such that they view the bearings as the train passes the site. A signal indicative of the heat energy from each bearing is then transmitted to a central office where the data are interpreted by a skilled operator who advises the train crew by radio as to which car and bearing are suspect. Alternatively, the processed heat signal may be reported directly to the train crew - either by a wayside "scoreboard" displaying an axle-count to the rear of the train from the suspect bearing or by a voice synthesizer unit or "talker" reporting over the train radio. Today there are approximately 500 hot box detectors on CP and CN main lines.

Trackside devices are also utilized for the detection of overheated wheels, out-of-round wheels, dragging equipment, overloaded cars and shifted loads, all of which are potential causes of train accidents.

Computer Technology

Railways were one of the first major industries to enter the computer age with the use of data processing equipment for the handling of their inherently large volumes of accounting and financial data. Computer-based information systems now in place on major Canadian railways provide real-time data on movement and status of all cars on line and a wide variety of other data to satisfy managerial and customer needs. One of the more recent enhancements on some railways is a computer-to-computer link between the railway and the shipper.

Computer technology has also permeated all of the many vital technical activities required to support operations, with resulting major improvements in productivity and safety.

Track

The rapid increase in the number of 263,000 lb. gross weight freight cars (100-ton capacity) and higher horsepower locomotives during the 1960's and 70's quickly resulted in a requirement for a stronger track structure to reduce replacement and maintenance costs. Various measures have been taken in response to this requirement, including the following:

- replacement of the 100 or 115 lb. (per yard) rail on main lines with 132 or 136 lb. rail;
- use of continuous welded rail in lieu of 39 or 78 ft. lengths bolted together;
- use of alloy and/or heat-treated rail in curves to reduce wear;
- increase in depth and width of the ballast section and improvement in ballast quality;
- use of geotechnical fabrics to improve drainage;
- use of all-welded turnouts at some locations;
- use of concrete ties by some railways;
- use of sophisticated inspection cars to monitor track quality and produce reports in real-time for various purposes such as immediate corrective track maintenance and long-term maintenance planning and budgetting.

The formerly labour-intensive tasks of track maintenance and rehabilitation are now accomplished by a much smaller work force and a large inventory of machinery specifically designed for the work. The inventory includes microprocessor-controlled tamping and lining machines, machines for replacing ties, cleaning ballast and numerous other types.

4. ONGOING TECHNOLOGICAL DEVELOPMENTS AND RESEARCH

Substantial advances have been made over the past two decades towards increasing railway productivity and reducing operating costs, through technological development. Efforts to further reduce costs are continuing and some of the most promising of these are summarized in the following.

Radial Axle Trucks

Initial development of the so-called radial axle trucks arose from investigations in the late 1960's and early 1970's into excessive rail and wheel wear following the introduction of 3-axle locomotives and 100-ton capacity cars. Common to the several such trucks developed, are modifications to resist those forces which result in a high angle of attack of the leading wheelset on the outer rail and excessive wheel wear and track damage. Extensive comparative testing of these types of trucks in revenue service, some of which is still in progress, has shown that flange wear on the wheels of certain of these trucks is only 20% of that on the wheels of conventional trucks and tread wear only 60%.

An additional important benefit of the radial axle truck is that self-excited oscillation (hunting) of the trucks on tangent track is much reduced. With conventional trucks, this hunting, which is normally most severe under an empty car, may be of sufficient severity to cause derailment. More than 1600 radial axle trucks are now in revenue service in Canada.

Reductions in Freight Car Weight

Light Weight Materials for Carbody Construction

Through the use of high strength steel, aluminum, or other material such as fibreglass reinforced polyester in the carbody construction, the tare

weight of a freight car can be reduced and the payload correspondingly increased. In the case of aluminum cars, for example, the increase in payload can be in the order of 7 to 10% and can result in substantial savings in railway operating costs. New designs to maximize such savings continue to be developed.

Slackless Drawbars

In long heavy trains, the slack action permitted by standard draft gear can result in very high coupler forces, particularly in undulating territory. Such forces can result in damage to track or equipment and even derailment. Efforts to minimize such occurrences have led to the concept of an inter-car coupler totally free of slack, i.e., a slackless drawbar.

Although theoretically all cars in a train could be equipped with slackless drawbars, railway operating conditions suggest blocks of only 5 or 10 such cars, with each such block being connected to the next block by standard couplers. In a continuing revenue service test on a railway in the USA of a unit coal train made up of 10 blocks of 10 slackless drawbar cars, maximum in-train forces were found to be only 20% of those occurring in a similar train equipped with standard couplers and draft gear operating on the same route.

The use of slackless drawbars would have the additional benefit of reducing car weight by approximately 1,500 lb. per car because they are lighter than the conventional coupler and draft gear. Also, it is probable that the reduction to in-train forces would enable re-design of the centre sill, with further weight reductions. Car maintenance costs, however, might increase because of having to handle a block of five or ten cars through the maintenance facility, rather than just a single car.

Reducing Train Resistance

Improving Aerodynamic Qualities

To obtain data on the extent of fuel savings that might be achieved through a reduction in aerodynamic drag on bulk commodity unit train

equipment, wind tunnel tests were made by the AAR in 1984 and 1985 using scale models of such equipment. On the basis of the findings from those tests, computer simulation runs were made of unit coal trains over a 350-mile route between a mine and a power plant in the fairly level midwestern United States. Five trains of one hundred 101-ton cars each were compared; one each of gondola cars with and without covers, one each of hopper cars with and without covers and one of streamlined uncovered gondola cars.

It was found that the addition of covers to the gondola car consist reduced the fuel consumption for the round trip by approximately 1500 gals. (US) or 13%. For the hopper car consist, the addition of covers reduced fuel consumption by approximately 900 gals. (US) or 8%. Streamlining saved approximately 700 gals. (US) or 7%.

Rail Lubrication

Considerable testing conducted over the past several years has established that reducing train resistance through continuous lubrication of the rails will result in significant fuel savings. Several different rail lubrication systems for installation on locomotives or other rail vehicles are now available and evaluation of these, for their own use, is in progress on various North American railways.

AC Traction

Increased productivity and reliability of diesel-electric locomotives and significant reductions in maintenance costs are possible through utilization of AC traction motors in place of the DC motors which historically have been employed on North American diesel locomotives. Technological developments over the past decade have substantially increased the economic feasibility of AC traction for North American application and considerable activity directed to performance evaluation of the system is underway in Canada and the USA.

Rail Profile Grinding

On heavy traffic lines with a high density of curved track, it may be necessary to grind the rail as often as every four months to remove

corrugations and other damage to the rail head. Such grinding (corrective grinding) reduces the service life of the rail.

Considerable success has been achieved in prolonging the life of rail in curves through a relatively new process known as rail profile grinding. It consists of utilizing the rail grinding train to modify the cross-sectional profile of the head of the rail in order to change the geometry of the rail-wheel contact. The modified rail profile results in a reduction to the very high contact stresses which occur at critical points on the rail head, thereby decreasing the rate of growth of corrugations.

Recent laboratory research and analysis has shown that by combining profile grinding with more frequent and lighter grinding cycles (preventive grinding) the formation of corrugations can be prevented. It has been estimated that rail profile grinding combined with preventive grinding, as compared to the past procedure of corrective grinding only, can result in up to a threefold increase in rail life.

Concrete Track Ties

A reduction in track and equipment maintenance cost and in the risk of derailment can result from the use of concrete track ties in lieu of wood ties. Although their high initial cost has so far discouraged their widespread use by North American railways, the number of concrete ties being installed is increasing.

Rear-of-Train Telemetry

Technology has been developed in the form of rear-of-train equipment which enables elimination of the caboose from most freight trains, with consequent savings in caboose ownership and maintenance cost. This equipment collects the data necessary for safe train operation (formerly monitored by the crew in the caboose) by means of an electronic device located on the trailing end of the train's last car and sends the data by radio to receiving and display equipment in the locomotive cab.

Rear-of-train telemetry equipment has been in operational service in the

USA since 1984 and in December of 1987 was approved by the Canadian Transport Commission for service in Canada.

Locomotive Event Recorders

On-board systems to monitor the operation of locomotives, commonly referred to as event recorders, are being increasingly used by North American railways. These devices are capable of monitoring train handling parameters, such as changes in speed, throttle position, and use of brakes, and also important indicators of engine performance.

Like the black boxes utilized in aircraft, event recorders can play a valuable role in post-accident investigations. Additionally, the data collected is useful in discussion with train crews with a view to improving train handling performance, and in the training and qualifying of candidate locomotive engineers. The information collected on engine performance can be utilized by maintenance personnel in preventive maintenance activities. Both major Canadian railways are currently engaged in equipping their road locomotive fleet with recorders.

Advanced Train Control System

North American railways are currently cooperating in the design and development of a new and specialized train control system known as the Advanced Train Control System (ATCS). ATCS will make the fullest use of the most recent advances in microprocessor and telecommunication technologies and will be immediately applicable to CTC, MBS or manually operated systems. ATCS will bring about the migration to the central office, of safety functions that traditionally were located at trackside and the creation of a "smart" train, a train with locomotive-based microprocessor intelligence. The system represents the latest step in the evolution of train control and is expected to have a significant positive impact on the efficiency and safety of train operations.

High Productivity Integral Train

The High Productivity Integral Train (HPIT) development was initiated by the AAR in 1984 through a request to the North American railway supply industry for expressions of interest in a program to promote the development of advanced-technology unit trains. Proposals for eight different intermodal trains and five bulk commodity trains were received. Current status of the developments varies from still incomplete design through prototype construction and testing of components to revenue demonstration service.

Each proposed design includes features to increase productivity and reduce cost. Slackless drawbars, lightweight aluminum cars, radial axle trucks, radio controlled remote locomotive consists and other innovations are included in the bulk commodity train designs. Although it is not expected that all of the proposed systems will come to fruition, it appears on the basis of analysis and testing carried out in the USA to date, that some positive impacts on productivity and costs will result from the program.

5. DISCUSSION

Generally, the rail transportation problems identified by the mine representatives are not fundamental faults in the system. Although the problems are not inconsequential, for they all result in cost increases (mostly to the mine operators), it is evident that their correction is a matter of adjustments to the system rather than its re-design.

The problems of late delivery of empty trains for loading, non-uniform heights of cars and non-functioning drains in some cars can only be rectified by the railway company involved. With respect to the problem of freezing of the coal, the Department of Energy Mines and Resources Canada, through the Coal Research Laboratories of CANMET, has awarded a contract to carry out a review of the state-of-the-art in coal freezing in railway cars and the development of a proposed program of applied research directed to controlling the problem. It is expected that the work will be completed in 1988.

As to the concerns expressed by the producers with respect to the high proportion of their total costs attributable to transportation, most of the ongoing technological developments discussed hold promise for future reductions in railway operating costs, which should serve to at least partially offset the effects of inflation on coal tariffs. Slackless drawbars in particular appear to have appreciable potential for reducing operating costs and, on the basis of work done by the AAR on aerodynamic drag, direct benefits to the coal industry may be a possibility through the use of covers on the coal cars. However, in both cases, work is needed to verify these possibilities. Recommendations for such work follow in Part 6 of this summary.

To bring about a reduction in tariffs, a very large gain in transport productivity would be needed. The advanced-technology, bulk commodity High Productivity Integral Train (HPIT) developments now underway in the USA have potential for such a gain. Another concept with potential may be the "High Efficiency Coal Car for Unit Train Service" proposed by the National Steel Car Company of Hamilton, Ontario.

6. RECOMMENDATIONS

It is recommended that the following activities be undertaken directed to exploring the potential for reductions in the cost of rail transportation of coal.

1. Covers on Coal Cars

   a) Conduct simulation runs of typical Canadian unit train consists on the routes between the Western Canada coal mining area and both a west coast ocean terminal and the Thunder Bay terminal, with the purpose of ascertaining the approximate fuel saving that would result from the use of cars with covers compared to cars without covers.

   b) If the simulation runs with covers indicate the likelihood of sufficient fuel savings to justify the use of covers, ascertain, through discussion with the mine operators and the railways, whether it is believed a lift-off cover system is a practicable method for controlling coal dust blow-off.

2. Slackless Drawbars

Develop the following estimates:

a) Reduction in weight and purchase cost that would likely be possible for:

(i) a coal car that is to be connected to the two adjacent cars with slackless drawbars;

(ii) a coal car that is to be connected to the adjacent car at one end with a slackless drawbar and to the adjacent car at the other end with a conventional coupler and draft gear.

as compared, in each case, with a car that is connected to the adjacent car at each end with a conventional coupler and draft gear.

b) Increase in costs (if any) that would result from the operation of blocks of slackless drawbar connected cars in a train, such costs being attributable to:

(i) additional car maintenance costs
(ii) additional car ownership costs.

Two estimates should be made; one for the case of 5-car blocks and one for the case of 10-car blocks.

3. High Productivity Trains

a) Ascertain, through discussion with the AAR and other involved parties, the present status of, and future developments for, the bulk commodity unit train concepts which resulted from the High Productivity Integral Train (HPIT) program.

b) Ascertain, through discussion with National Steel Car and other involved parties, the present status of the "High Efficiency Coal Car for Unit Train Service" proposed by the National Steel Car, of Hamilton, Ontario,.

SOMMAIRE

1. INTRODUCTION ET OBJECTIFS

Les principales mines et réserves de charbon du Canada se trouvent surtout en Colombie-Britannique orientale, dans les parties centrale et occidentale de l'Alberta et dans le sud de la Saskatchewan. C'est dire que ce charbon doit être transporté par chemin de fer sur de grandes distances et aussi que les sociétés minières sont directement concernées par le coût et la qualité des services de transport ferroviaire. De plus, étant donné la place vitale qu'occupe le charbon dans l'économie du pays, cette question prend la même importance tant au niveau fédéral qu'au niveau provincial. De leur côté, les sociétés ferroviaires ont beaucoup à gagner lorsque l'industrie du charbon est en bonne santé. En effet, les 34 millions de tonnes qu'elles ont transportées en 1986 ont constitué près de 19 p. 100 de toutes les livraisons par rail et leur ont rapporté 662 millions de dollars.

Cette recherche consistait principalement à cerner les problèmes inhérents au transport ferroviaire du charbon au Canada, du point de vue des sociétés productrices. Des réunions avec cinq parmi les plus importantes d'entre elles ont permis d'atteindre cet objectif. Le second objectif consistait à faire un tour d'horizon de l'état actuel des techniques de transport par chemin de fer et de résumer les travaux de recherche et de développement en cours.

2. POINT DE VUE DES SOCIÉTÉS PRODUCTRICES

En gros, les sociétés productrices de charbon estiment que les chemins de fer font de leur mieux pour fournir les services qu'on leur demande, mais que, les distances étant ce qu'elles sont, la question du coût ne cesse de les inquiéter. Outre le coût, elles ont mis en évidence d'autres préoccupations que nous résumons ci-après.

Retards dans l'acheminement des trains vides

Malgré l'existence de programmes préétablis, des retards d'acheminement sont souvent constatés. Lorsqu'un train arrive en retard dans une mine qui ne fonctionne pas 24 heures sur 24, une équipe de chargement doit être appelée à la mine et être payée au tarif des heures supplémentaires. Il y a aussi le risque de voir les silos s'engorger et déborder si on les remplit avant l'arrivée du train et, au point de déchargement, le risque de surcoût dû à la désorganisation dans le programme de déchargement des trains venus d'autres sites miniers.

Difficultés de déchargement

Au point de déchargement, les wagons pleins sont basculés et se vident sous l'effet de la pesanteur. Cependant, par temps froid, il arrive parfois que l'humidité contenue dans le charbon fait que celui-ci gèle et reste pris dans le wagon. À Thunder Bay, même si ce problème est réglé grâce à l'existence de chambres de dégel, l'opération reste onéreuse.

Dans les ports de la côte Ouest, le problème du gel est moins aigu qu'à Thunder Bay en raison de températures plus clémentes le long du parcours et des trajets plus courts. Toutefois, il n'y a pas de chambres de dégel, de sorte que si le charbon gèle dans un wagon, le déchargement se fait avec beaucoup de difficulté. Cependant, en général, les sociétés productrices estiment que le problème du gel n'est pas grave au point de nécessiter des immobilisations onéreuses pour le régler.

À part le gel, il y a également le problème d'évacuation du charbon; en effet, des restes de l'ordre d'une tonne ont pu être constatés dans certains wagons dont les orifices fonctionnent mal, entraînant l'accumulation de charbon compacté autour de ces orifices.

Rejet de poussières de charbon dans l'atmosphère

Dans le but de prévenir ces rejets, la charge est arrosée d'un agent chimique liquide qui coûte près de 10 ¢ la tonne. Aux dires des intéressés, cela revient encore moins cher que le bâchage des wagons.

Autres problèmes

Présence de quantités parfois importantes d'eau dans les wagons au moment du chargement, probablement due à un orifice d'évacuation engorgé ou fonctionnant mal. Écarts dans la hauteur des wagons, ce qui ralentit l'opération de chargement. Possibilité que les trains-blocs commencent à manquer si les ventes de charbon continuent de progresser. Le représentant qui a soulevé cette question a dit que la société ferroviaire desservant sa mine avait déjà pris en location aux États-Unis quelque 300 wagons. Il a ajouté que, lorsque cette société doit effectuer des acheminements par trains incomplets, elle utilise des wagons-trémies dont il est dit qu'il y a pénurie.

3. TRANSPORT PAR CHEMIN DE FER - TOUR D'HORIZON DES TECHNIQUES

Les quarante dernières années ont vu une évolution marquante des chemins de fer nord-américains. D'abord, les locomotives à vapeur ont été remplacées par des diesel-électriques, moins polluantes et plus performantes. Ensuite, le wagon couvert polyvalent a presque disparu, remplacé par une vaste gamme de wagons spécialisés, de forte capacité, assemblés pour former des trains-blocs composés d'une centaine de ces wagons. L'infrastructure de la voie a été grandement renforcée, des systèmes de commande plus modernes ont été implantés et l'ordinateur règne maintenant en maître. Ayant souvent pris les devants, les sociétés ferroviaires canadiennes ont maintenant la réputation d'être à l'avant-garde en matière de techniques avancées.

Matériel de traction et wagons

Les premiers changements importants de cette évolution ont eu lieu vers la fin des années 40, lorsque les premières grosses commandes de locomotives diesel ont été placées. Au début des années 60, la conversion à la traction diesel était achevée. Les premières locomotives diesel développaient de 1 000 à 1 500 Hp, mais l'essor a été si rapide que, vers la fin de 1985,

presque la moitié des unités en service avaient une puissance de 3 000 Hp ou plus. Les locomotives que le CN vient de commander ont une puissance de 3 800 à 4 000 Hp.

L'effort de traction des locomotives diesel sur rampe a pu être augmenté de 50 p. 100, ou plus, grâce à des dispositifs anti-patinage. Conséquence de la diminution de la puissance de traction à mettre en oeuvre, le poste "Combustibles" a diminué ainsi que le nombre des locomotives elles-mêmes. D'autres économies de combustible ont également pu être réalisées grâce à la mise au point d'un turbo-compresseur et d'autres organes de moteur plus performants, tel un dispositif permettant d'arrêter les moteurs des locomotives de traction d'un train-bloc et de les relancer au moment voulu.

Une évolution aussi marquante s'est produite dans la composition du parc matériel à marchandises, au Canada et aux États-Unis. Les wagons couverts qui, à un moment donné, étaient plus nombreux que toutes les autres familles de wagons réunies, ne représentent plus que 40 p. 100 du parc canadien. Les wagons tombereaux et wagons-trémies d'une capacité de chargement de 80 tonnes qui servaient au transport du vrac ont été remplacés par un matériel de 100 tonnes et plus. Enfin, les wagons couverts polyvalents en bois, dont la capacité de chargement était de 40 à 50 tonnes, ont cédé la place à un matériel en acier d'une capacité entre 60 et 80 tonnes.

L'essor du transport intermodal sur wagons plats (conteneurs et semi-remorques) a fait naître de nouvelles familles de wagons plats où la plate-forme est remplacée par des plateaux. La longueur utile des wagons peut être prolongée en attelant plusieurs plateaux les uns aux autres par des barres de traction sans jeu, ce qui permet de négocier aisément les courbes, seul l'attelage à chacun des deux bouts libres étant du type standard. Il y a aussi la famille des wagons dont le bogie comporte un seul essieu et non plus deux, et les wagons capables de transporter deux conteneurs empilés, au lieu d'un seul.

Trains-blocs

Le procédé du train-bloc permet de maximiser les gains de productivité réalisés grâce à la capacité accrue des wagons et à la mise en oeuvre de locomotives plus puissantes. Un train-bloc constitue une rame indéformable qui va de bout en bout d'un parcours rigoureusement établi. Ce type de train peut transporter des marchandises très diversifiées (charbon, grains, minerai, véhicules moteur, conteneurs et remorques) et sa productivité est élevée en raison d'un fort taux d'utilisation des wagons et d'une réduction des manutentions.

Des terminus sont construits exprès pour le chargement et le déchargement automatiques des trains-blocs qui, dans le cas des marchandises en vrac, comptent typiquement une centaine de wagons. Les terminaux intermodes sont équipés de portiques puissants et de chariots élévateurs à fourche pour le chargement et le déchargement des conteneurs et des remorques.

Traction répartie dans la rame

Un mode d'exploitation qui s'est répandu au cours des deux dernières décennies consiste à répartir dans la rame des unités motrices commandées par radio à partir de la tête du train. Les grands avantages de ce mode sont la:

- réduction de l'effort au crochet, autorisant la mise en oeuvre de convois plus lourds sur une rampe de même inclinaison,

- réduction de la distance de freinage, grâce à une réponse en freinage plus rapide,

- réduction des risques d'avarie par une qualité de roulement améliorée due à un effort de freinage moins brutal et plus régulier.

Systèmes de commande des trains

Ordres de marche

Le but essentiel de tout système de commande des trains est d'assurer la sécurité et l'efficacité du trafic ferroviaire de bout en bout. Dans les années mil huit cent cinquante, l'avénement de la télégraphie a fait que la circulation des trains par ordre de marche a pu se répandre rapidement en Amérique du Nord, venant remplacer les méthodes du temps, moins sûres et moins efficaces. Un ordre de marche est une autorisation écrite émanant du régulateur du poste de commande central et remise de main à main par un chef de gare à l'équipage de conduite d'un train. Il autorise un train donné à occuper un canton particulier de la voie à un moment précis. Actuellement, certains itinéraires peu circulés au Canada fonctionnent encore selon cette procédure.

Cantonnement automatique

Dans les années 40, les sociétés ferroviaires canadiennes ont adopté le cantonnement automatique parallèlement aux ordres de marche. Il consiste à découper la voie en un certain nombre de tronçons ou cantons, protégés chacun par un signal fixe. L'intérêt de ce système est que les signaux sont manoeuvrés automatiquement par les trains eux-mêmes, la présence d'un train à l'intérieur d'un canton étant détectée par un circuit de voie dont les conducteurs sont formés par les rails de la voie. Sur les axes très circulés, le cantonnement automatique apporte une protection et autorise un débit de loin supérieur à ceux des ordres de marche. Bien que la commande centralisée de la circulation ait commencé à remplacer graduellement le cantonnement automatique sur les lignes du CN et du CP, ces sociétés exploitent encore plus de 2 600 milles de voies fonctionnant toujours en automatique.

Commande centralisée de la circulation (CCC)

Le premier réseau CCC au Canada remonte à 1941. À partir d'un P.C. central, le régulateur commande l'ensemble des signaux et des aiguillages protégeant

les voies dans une zone d'action donnée. Grâce au CCC, le régulateur suit à distance la marche des trains, les dirige, les gare sur les voies d'évitement, manoeuvre les aiguillages et sait, à chaque instant, grâce à des signaux visuels et auditifs, où se trouve chacun des trains placé sous son contrôle. Un des avantages de la CCC est aussi de réduire le personnel affecté à la régulation.

Mais ce n'est pas tout. Grâce à la microélectronique, l'ordinateur peut soulager le régulateur d'une partie de sa tâche. Ainsi, la régulation assistée par ordinateur existe maintenant dans plusieurs des grands centres ferroviaires du pays. Elle possède des caractéristiques supérieures à celles de la CCC non informatisée.

La CCC autorise aussi la banalisation des voies, c'est-à-dire qu'elle permet d'exploiter une voie unique dans les deux sens et de lui donner le même débit qu'une voie double à cantonnement automatique. Actuellement, le total des voies exploitées en CCC par les deux grandes sociétés ferroviaires du pays s'élève à quelque 8 000 milles.

Block manuel

Le block manuel existe au Canada depuis les années 60 pour la protection des voies à faible débit ne justifiant pas un système automatique ou centralisé. Avec cet équipement, le cantonnement se fait par radio et non plus par ordres de marche écrits.

Le block manuel est appuyé, ou le sera bientôt, par un système électronique équipé d'un écran de visualisation donnant au régulateur une vue d'ensemble de sa zone d'action et d'un poste de communication plus performant. Au Canada, près de 22 000 milles de voies sont équipées de ce système.

Électrification

En 1976, une étude menée sur l'électrification des chemins de fer au Canada a établi que le projet était techniquement faisable. Cependant, à l'époque, l'intérêt d'électrifier le réseau ne s'est trouvé justifié ni sur le plan opérationnel qui intéresse les sociétés ferroviaires, ni sur le plan de l'économie qui intéresse le pays.

Néanmoins, les études qui ont été faites par la suite ont été plus convaincantes. Ainsi, la BCR a décidé d'électrifier le branchement de Tumbler Ridge, long de 82 milles, qu'elle avait l'intention de construire pour transporter le charbon tiré des gisements du nord-est de la Colombie-Britannique. Achevée en 1983, c'est la seule ligne de transport de marchandises à avoir été électrifiée au Canada; elle est, en plus, l'une des trois au monde à fonctionner sous 50 kV 60 Hz.

Surveillance au sol des trains

La modernisation des équipements de surveillance au sol a été un facteur important dans l'accroissement de la sécurité des opérations ferroviaires au cours des trente dernières années.

Il est à noter particulièrement la détection des boîtes d'essieux en surchauffe grâce aux capteurs thermiques installés des deux côtés de la voie, à la hauteur de ces boîtes. Lorsqu'une de ces boîtes émet une forte chaleur, le détecteur transmet un signal au poste de commande où il est analysé par un spécialiste qui, aussitôt, avertit l'équipe de conduite du train quant à la boîte exacte soupçonnée de surchauffer. L'avertissement peut être lancé en phonie de vive voix ou par une voix artificielle; il peut également se faire par un panneau à messages en bordure de voie qui indiquera alors l'essieu menacé, par son rang à partir de l'avant. Le nombre de ces détecteurs équipant les principales lignes du CN et du CP s'élève aujourd'hui à près de 500.

Il existe également en bordure de voie des dispositifs qui servent à détecter les roues en surchauffe ou ovalisées, un objet traînant, les wagons en surcharge, les charges désarrimées, autant de causes potentielles d'accident.

Informatisation

Les chemins de fer ont été parmi les premières grandes industries du pays à s'informatiser pour assurer un traitement plus rapide des quantités énormes de données comptables et financières. Les systèmes informatiques actuels donnent en temps réel la position et l'état de tous les wagons en service et produisent des données de toutes sortes valables tant pour la direction que pour les clients. L'un des derniers perfectionnements adoptés par certaines sociétés est la liaison "ordinateur-ordinateur" établie entre la société ferroviaire et ses clients expéditeurs.

L'informatisation a pénétré également toutes les activités techniques à l'appui des opérations, apportant un relèvement sensible de la productivité et de la sécurité.

Voie ferrée

L'essor rapide du trafic lourd durant les années 60 et 70 - multiplication des wagons d'une capacité de chargement de 100 tonnes (poids total en charge de 263 000 lb), et puissances de traction accrues - a fait naître la nécessité de renforcer l'infrastructure des voies, faute de quoi les coûts de renouvellement et d'entretien auraient monté en flèche. Diverses mesures ont donc été prises en conséquence, à savoir:

- remplacement sur les grandes lignes du rail de 100 ou 115 lb (la verge) par du 132 ou 136 lb;

- emploi de longs rails soudés au lieu des rails de 39 ou 78 pieds de long, éclissés les uns aux autres;

- mise en place dans les courbes de rails en acier allié, traité thermiquement ou non, afin de réduire l'usure;

- augmentation de la profondeur et de la largeur du ballast, et amélioration de ses qualités granulométriques;

- emploi de géotextiles pour améliorer le drainage;

- emploi sélectif de branchements soudés;

- emploi de traverses en béton par certaines sociétés;

- contrôle de la qualité de la voie par des voitures d'auscultation et production de rapports en temps réel utiles en maintenance corrective ou pour établir des prévisions en maintenance préventive.

Les campagnes de maintenance et de réfection des voies, autrefois si coûteuses en main-d'oeuvre, se font désormais par des équipes beaucoup plus réduites appuyées par un matériel tres varié conçu exprès: bourreuses-niveleuses-ripeuses, dégarnisseuses-cribleuses, machines à substituer les traverses, etc., toutes commandées électroniquement.

4. TRAVAUX DE R&D EN COURS

Le développement technologique a, au cours des deux dernières décennies, fait beaucoup de progrès dans le double but d'accroître la productivité et de réduire les coûts d'exploitation. Toutefois, les efforts ne s'arrêtent pas là et la recherche se poursuit dans divers domaines, dont voici un aperçu.

Bogies à essieux orientables

L'étude de ce type de bogie a commencé à l'issue des enquêtes faites vers la fin des années 60 et au début de la décennie suivante sur l'usure prononcée des rails et des roues, causée par la mise en service de la locomotive à trois essieux et du wagon de 100 tonnes de chargement. Les divers bogies à essieux orientables étudiés permettent d'atténuer les efforts qui font que l'essieu menant du bogie attaque le rail extérieur à un angle très ouvert, ce qui a pour conséquence l'usure accélérée des roues et les avaries de voie. Les essais comparatifs exhaustifs des divers types de bogies à essieux orientables en service payant, lesquels n'ont d'ailleurs pas tous été terminés, ont montré que certains bogies permettent de réduire l'usure du boudin des roues de 80 p. 100 comparativement aux bogies standard, et celle de la table de roulement de 40 p. 100.

Un autre avantage intéressant du bogie à essieux orientables est la nette réduction du lacet (phénomène d'auto-excitation qui se constate en alignement). Dans le cas d'un wagon vide équipé de bogies standard, le lacet peut parfois mener au déraillement. Plus de 1 600 bogies à essieux orientables équipent maintenant des wagons en service payant au Canada.

Allégement du matériel à marchandises

Allégement de la carrosserie

Par l'utilisation d'un matériau haute résistance (acier, aluminium ou polyester renforcé de fibres de verre), la tare du matériel à marchandises peut être diminuée et la charge utile accrue en conséquence. Dans le cas de

l'aluminium, par exemple, la charge utile peut être accrue de l'ordre de 7 à 10 p. 100, apportant d'intéressantes économies d'exploitation. De nouvelles familles sont constamment à l'étude dans le but de maximiser ces économies.

Barres de traction sans jeu

Les efforts s'exerçant sur un attelage standard peuvent être d'autant plus élevées que le convoi est long et le terrain accidenté; ils peuvent même parfois entraîner des avaries, voire des déraillements. La recherche de moyens pouvant atténuer ces efforts a mené à l'idée de l'attelage totalement rigide: la barre de traction sans jeu.

Bien que théoriquement tous les attelages sur un convoi pourraient être du type sans jeu, les sociétés ferroviaires ont trouvé qu'il suffisait d'en équiper des blocs de 5 à 10 wagons, reliés entre eux par des attelages standard. Aux États-Unis, un essai en service payant a été fait avec un train-bloc formé de 10 blocs comportant chacun 10 wagons équipés de barres de traction sans jeu. Il a été constaté que les efforts maximums en marche représentaient 20 p. 100 de ceux d'un train équipé d'attelages standard sur la même ligne.

Un autre avantage des barres de traction est d'apporter un allégement de quelque 1 500 lb par wagon, comparativement à l'attelage standard, sans compter l'allégement supplémentaire autorisé par une nouvelle longrine centrale qui n'aurait plus à être aussi lourde. Par contre, la maintenance risquerait d'être plus coûteuse car elle porterait sur un bloc de cinq à dix wagons à la fois et non plus sur un seul wagon.

Réduction de la résistance à la marche

Aérodynamique améliorée

Pour connaître l'ampleur des économies de combustible réalisables grâce à une réduction de la résistance à la marche des trains-blocs de marchandises, des essais en soufflerie ont été faits par l'AAR en 1984 et 1985 à l'aide de maquettes. Ensuite, en se servant des résultats tirés de ces essais, on a procédé par simulation assistée par ordinateur à la marche de trains-blocs charbonniers parcourant une distance de 350 milles entre une mine de charbon et une centrale thermique, quelque part dans les plaines du Midwest américain. La recherche a porté sur cinq trains de 100 wagons d'une capacité de 100 tonnes soit: un train de wagons tombereaux bâchés et un autre de non bâchés; un train de wagons trémies bâchés, mais de forme plus aérodynamique.

Il a été constaté que: le bâchage des wagons tombereaux a permis d'économiser sur un aller et retour quelque 1 500 gallons américains, soit un gain de 13 p. 100; le bâchage des wagons trémies a fait économiser près de 900 gallons américains, soit un gain de 8 p. 100; les wagons tombereaux plus aérodynamiques permettent une économie de 700 gallons américains, environ, soit un gain de 7 p. 100.

Lubrication des rails

Les essais exhaustifs des dernières années ont montré que, en réduisant la résistance à la marche, la lubrification en continu des rails apporte des économies de combustible. Il existe actuellement divers systèmes de lubrification à installer soit sur les locomotives, soit sur le matériel tracté, et les sociétés ferroviaires nord-américaines sont en train de les mettre à l'essai pour en déterminer l'utilité en ce qui les concerne.

Traction en alternatif

Le remplacement des moteurs de traction en continu, qui ont toujours été utilisés sur les locomotives diesel en Amérique du Nord, par des moteurs en alternatif permettra non seulement de relever la productivité et la fiabilité des locomotives diesel-électriques, mais aussi d'en réduire les coûts d'entretien. Les perfectionnements apportés au cours de la dernière décennie aux moteurs de traction en alternatif ont accru leur intérêt économique en applications ferroviaires, de sorte que, actuellement, tant au Canada qu'aux États-Unis, ils sont soumis à une évaluation intensive de leurs performances.

Reprofilage des rails

Sur les axes lourds et sinueux, il est nécessaire de meuler les rails parfois tous les quatre mois afin d'éliminer l'usure ondulatoire et les autres avaries qui atteignent le champignon. Il va sans dire que les meulages fréquents (dits correctifs) réduisent la durée de vie de ces rails.

Or, un nouveau procédé permet de prolonger la vie des rails courbes; c'est le profilage qui consiste à donner au champignon un profil destiné à améliorer le contact géométrique roue-rail de manière à réduire les contraintes élevées se produisant en certains points névralgiques du champignon et, ainsi, réduire la croissance de l'usure ondulatoire.

Des essais et des analyses en laboratoire ont montré que, en conjuguant le reprofilage à un régime de meulage plus fréquent mais plus léger (régime préventif), il est possible d'éliminer tout à fait l'usure ondulatoire. De plus, ce procédé permettra de tripler la durée de vie des rails, comparativement au procédé antérieur.

Traverses en béton

Par rapport aux traverses en bois, les traverses en béton promettent une réduction du coût de l'entretien des voies et des équipements de voie ainsi que des risques de déraillement. Bien que leur coût initial élevé ait jusqu'ici fait hésiter les sociétés ferroviaires à en généraliser l'utilisation, leur nombre ne cesse de croître.

Surveillance en queue de train

Les progrès technologiques permettent désormais aux sociétés ferroviaires de se défaire du wagon de queue sur la plupart des convois de marchandises et

de le remplacer par un matériel de surveillance électronique moins coûteux à garder et à entretenir qu'un wagon. Ce matériel informatisé, fixé à l'attelage du dernier wagon, recueille toutes les informations dont se chargeait autrefois l'équipe de surveillance et les transmet par radio à la cabine de conduite où elles sont affichées. La surveillance électronique en queue de train s'utilise aux États-Unis depuis 1984 et, en décembre 1987, son utilisation au Canada a été approuvée par la Commission canadienne des transports.

Enregistreurs-marqueurs d'événements

L'utilisation à bord des locomotives d'appareils destinés à enregistrer les paramètres de fonctionnement, appelés aussi enregistreurs-marqueurs d'événements, ne cesse de prendre de l'ampleur en Amérique du Nord. Ils enregistrent au fur et à mesure les paramètres suivants: variations de vitesse, régime moteur et application des freins, en plus d'importants paramètres de fonctionnement renseignant sur la performance générale du moteur.

À l'instar des fameuses "boîtes noires" à bord des aéronefs, ces appareils sont appelés à jouer un rôle important lors d'une enquête sur les causes d'un accident. De plus, les données enregistrées permettent d'indiquer à l'équipage de conduite comment mieux conduire le train et servent aussi à la formation et à la qualification de nouveaux conducteurs. Quant aux données sur les performances du moteur, elles peuvent être utiles au personnel chargé de l'entretien préventif. Les deux grandes sociétés ferroviaires canadiennes sont en voie d'équiper de ces appareils leur matériel de traction grandes lignes.

Systèmes avancés de commande des trains

Les sociétés ferroviaires nord-américaines ont lancé un programme conjoint d'étude et de développement d'un nouveau système de commande appelé système avancé de commande des trains (SACT) qui fait largement appel à la télématique. Exploitable sur des voies à cantonnement automatique ou manuel ou en CCC, le SACT permettra de rapatrier les fonctions de sécurité qui, jusqu'ici, étaient implantées en bordure de voie, et aussi de doter les trains d'une "intelligence artificielle" embarquée. Il s'agit là de l'évolution ultime dans les systèmes de commande dont l'influence sur la sécurité et l'efficacité des opérations sera déterminante.

Trains-blocs à haute productivité

En 1984, l'Association of American Railroads a lancé un programme de mise au point de trains-blocs à haute productivité.

Elle a procédé par la voie d'un appel de propositions, invitant les constructeurs nord-américains de matériels ferroviaires à manifester leur volonté de participer à la mise au point de trains-blocs de technologie avancée. Les propositions reçues concernaient huit types différents de trains intermodaux et cinq trains marchandises pour le transport en vrac. À

l'heure actuelle, l'état d'avancement des différents projets va du stade des études à celui de l'exploitation expérimentale en service payant, en passant par la construction de prototypes et les essais de composants.

Chacun des projets soumis offre diverses caractéristiques visant à augmenter la productivité et à réduire corollairement les coûts. Barres de traction sans jeu, wagons légers en aluminium, bogies à essieux orientables, locomotives réparties dans la rame et télécommandées par voie hertzienne ainsi que d'autres innovations caractérisant les trains-blocs de transport en vrac. Si l'on ne s'attend certes pas à ce que tous ces projets arrivent à terme, il semble bien, à la lumière des analyses et des essais réalisés jusqu'à présent aux États-Unis, que le programme parrainé par l'AAR aura des retombées positives sur la productivité et le coût du transport ferroviaire des marchandises.

5. DÉBAT

De façon générale, les lacunes mises en évidence par les sociétés minières sont attribuables à des vices de conception. Bien que les problèmes engendrés ne soient pas sans conséquences (en effet, il y a toujours un surcoût que les sociétés minières doivent absorber en grande partie), il reste que le redressement est affaire de correctifs et non pas de réétude complète des systèmes.

Les problèmes de retards d'acheminement des trains au chargement, d'écarts dans la hauteur des wagons et de dérèglement mécanique de ceux-ci seront résolus par les sociétés ferroviaires. Quant à celui de gel du charbon dans les wagons, il pourra être réglé par un programme de recherche appliquée qui s'inspirera des techniques généralement utilisées et pour lequel Énergie, Mines et Ressources Canada a déjà accordé un marché par l'entremise des Laboratoires de recherche sur le charbon du CANMET. Les travaux devront être termines d'ici la fin de 1988.

Quant à la question du coût du transport, et de la part élevée qu'il prend dans le coût total d'exploitation, il est clair que la solution réside dans les recherches en cours. La plupart des recherches mentionnées dans ce document promettent de réduire les coûts de transport et d'effacer ainsi, au moins partiellement, les effets de l'inflation sur les tarifs charbonniers. Des techniques, telles les barres de traction sans jeu, semblent particulièrement porteuses de solution, ainsi que le bâchage des wagons, comme l'a d'ailleurs démontré la recherche faite par l'AAR sur la résistance à la marche des trains. Mais, dans ces deux cas, il restera à en faire la preuve par des recherches ultérieures que nous recommandons et qui sont explicitées dans la partie 6 du présent sommaire.

Cependant, pour que le coût du transport proprement dit puisse être réduit, un accroissement très net de la productivité est nécessaire. À ce titre, le projet du train-bloc à haute productivité que les États-Unis mettent au point pour le transport de produits en vrac est très prometteur, de même que celui du wagon charbonnier haute efficacité pour trains-blocs proposé par la National Steel Car Company of Hamilton en Ontario.

6. RECOMMANDATIONS

Il est recommandé de lancer les actions suivantes visant à vérifier les économies réalisables en transport ferroviaire du charbon.

1. Wagons charbonniers couverts

   a) Simuler la marche de trains-blocs canadiens types sur des itinéraires connus entre la région charbonnière de l'ouest du Canada et deux terminus, l'un sur la côte Ouest et l'autre à Thunder Bay, dans lebut de déterminer approximativement l'économie de combustible réalisable par l'utilisation de wagons couverts.

   b) Si la simulation débouche sur des résultats probants, vérifier auprès des sociétés minières et ferroviaires si l'utilisation d'éléments amovibles (capôt, bâche) peut constituer une solution au problème du rejet des poussières de charbon.

2. Barres de traction sans jeu

Faire les évaluations suivantes:

   a) Réduction de la tare et du coût d'achat réalisable avec:

      i) un wagon charbonnier attelé à chaque extrémité par des barres de traction sans jeu,

      ii) un wagon charbonnier attelé à une extrémité par une barre de traction sans jeu et à l'autre par un attelage standard,

   comparativement, dans chaque cas, avec celui d'un wagon attelé de part et d'autre par un attelage standard.

   b) Surcoût éventuel pouvant découler de l'utilisation de blocs formés de plusieurs wagons reliés entre eux par des barres de traction sans jeu, ce surcoût étant attribuable à une augmentation des:

      i) frais d'entretien,

      ii) frais d'acquisition.

   Évaluer parallèlement les cas de blocs formés de 5 et 10 wagons.

3. Train-bloc haute productivité

   a) Vérifier auprès de l'AAR, et d'autres intéressés, l'état actuel ainsi que les perspectives du concept du train-bloc haute productivité pour le transport du vrac, à la lumière du programme de recherche entrepris dans ce domaine.

   b) Vérifier auprès de la National Steel Car Co., et d'autres intéressés, l'état actuel de la recherche sur le wagon charbonnier haute efficacité et du programme que cette compagnie de Hamilton, Ontario, a lancé.

1. INTRODUCTION

The transportation of very large quantities of bulk material by rail is an essential component of the overall production and marketing process of the coal industry in most countries of the world. In Canada, the rail haul distances from mine to domestic user, or to seaport for export, are particularly long, and the quality and cost of service provided by the railways is therefore of particular importance to the coal mining industy. Because the coal industry constitutes such a significant factor in the Canadian economy, governments at both Federal and Provincial level share the industry's interest in these aspects of the service provided by the railways.

1.1 Objectives of the Work

This work was undertaken on behalf of the Transportation Development Centre (TDC) of Transport Canada. Its primary objective was to document the current problems associated with the rail shipment of coal in Canada as identified by the mine operators.

To satisfy this objective, two representatives of TDC along with the consultant travelled to Western Canada during the week of March 21 for meetings with a representative of each of five of the major coal companies as follows:

Crows Nest Resources Limited	-	R. D. Ansley, Manager, Marketing and Transportation
Esso Resources Canada Limited	-	Grant J. Goddard, Coordinator - Marketing Services
Fording Coal Limited	-	Lorne R. Lyndon, Supervisor, Marketing Services
Westar Mining	-	Terrance L. Garvey, Director, Transportation
Luscar Ltd.	-	Emile J. Dubois Manager, Transportation

The operating properties of the first four of these companies are served

by CP Rail (CP). The Luscar operating properties are served by the Canadian National Railway (CN). The British Columbia Railway (BCR) also provides unit train coal service, but not to these companies.

Problems identified by the coal company representatives are outlined in Section 2 of this report.

The second objective of the work was to prepare a description of the current state-of-the-art in rail transportation technology and a summary of current rail transportation technological development and research. These two portions of the work are included as Sections 3 and 4.

1.2 Relevant Background Information

The major producing Canadian coal mines and reserves lie largely in eastern British Columbia, mid and western Alberta and southern Saskatchewan. Coal for export must be moved considerable distances to the Pacific coast ports. Typically, the distance by rail from present mines in Alberta and British Columbia to the Pacific ports is 600 to 700 miles. In contrast, the average haul from mine to port in Australia is only 125 miles and in South Africa only 330.(1)

Distance also works against Canadian coal suppliers with respect to some important domestic customers. In the case of the very substantial Ontario Hydro coal requirements for the generation of electric power for example, coal purchased from American mines in Pennsylvania must be moved by rail over distances of between only 75 and 400 miles to the terminals at Lake Erie compared to the 1300 to 1400 mile distance between the British Columbia or Alberta mines and Thunder Bay.

In 1986, a total of nearly 34 million tons of coal were transported by Canadian railways for a total of approximately 25 billion ton miles.(1) Clearly, the service level which the railways provide and

(1) Numbers in brackets designate references listed at end of the report.

their operating costs are of vital importance to the coal industry. On the other hand, the continued requirement for rail transportation of Canadian coal, at present or higher levels, is of fundamental importance to the railway industry. The 34 million tons of coal they handled in 1986 constituted approximately 19% of all rail shipments and produced $662 million in revenues.(2) Thus to a large extent, these two important Canadian industries are dependent on one another for their continuing economic viability.

Both industries have achieved major productivity gains over the past 20 years. In the case of the coal industry, the undersea mines in Nova Scotia are the only large-scale underground coal-mining operations remaining in Canada. The more cost-effective surface mining systems are now being utilized throughout the western operations. Largely as a consequence of this, the tons of coal produced per employee-year grew from 1,280 in 1965 to 3,600 in 1982, almost a threefold increase.(3) Although no comparable single productivity figure is available for the Canadian railways involved in coal transportation, major gains have also been made in that industry as a result of the development of high-horsepower locomotives, high-capacity cars, the unit train concept and other developments discussed in Sections 3 and 4.

Most of the Canadian coal is moved from the loading point at the mine to the unloading terminal in unit trains consisting of locomotives and from 98 to 108 open top gondola cars. Car capacities range from 100 to as much as 104 short tons. There are also some less-than-unit train movements in bottom dump hopper cars. Most of the unit train equipment in coal service is owned by the railways, although Ontario Hydro and certain of the coal companies also own some. In all cases the equipment is operated by the railways.

In the loading process, empty unit trains pass under the mine's storage silo into which the coal has been elevated by conveyor. From the silo, the coal is chuted into the cars as they pass under. At destination, trains are unloaded into underground hoppers using rotary dumper equipment which rotates each individual car so that the contents are discharged downwards

into the hopper out of the top of the car. Special couplers on the cars enable rotation of the car without uncoupling. As the coal is unloaded it is transferred by special conveying equipment to the stockpiles, from where it is subsequently loaded into ships.

2. PROBLEMS IDENTIFIED BY MINE REPRESENTATIVES

2.1 General

Overall, the coal companies appear to feel that the railways are doing their best to provide them with the level of service they require. As already noted though, rail haul distances are great and consequently despite what is generally perceived by the coal companies as an effective system for handling their product, rail transport costs are high, and this is quite naturally a continuing and major concern of the coal companies. In one case, the rail transportation cost was said to be approximately 60% of the FOB price.

Other problems related to the rail operation identified by the coal company representatives are outlined below.

2.2 Delays in Arrival of Empty Trains for Loading

Schedules for arrival of empty trains for loading are developed in advance between the mine operator and the railway, taking into consideration mine production rate, capacity of the mine's storage silos, ocean/lake ship schedules and other pertinent factors. Despite the schedule, late arrival of empty trains frequently occurs.

Late arrival might or might not be serious, depending on circumstances. The mine must provide a crew for certain tasks in the loading operation. In cases where the mine is not operating 24 hours daily and the train arrives when there is no shift on duty, the loading crew must be called out and overtime rates paid. Also, whether or not the mine is operating on a 24 hour basis, a stockpiling problem may be created if the mine's storage silos are full and the train delay is significant.

In some circumstances, late arrival of a train for loading could result in extra costs at the unloading terminal due to conflict with the scheduled unloading times of trains arriving from other mines. In the worst case, departure of a ship might be delayed awaiting arrival of the coal from the delayed train.

2.3 Difficulties With Unloading Cars

Difficulties are sometimes encountered in completely unloading a car, in which case the mine pays more than once for the transportation of the coal that remains in the car. Two reasons for the difficulties were identified.

a) Freezing of the coal to the car side during transit

Freezing of course occurs only when temperatures are low and was said to be usually a consequence of the moisture that is present in the coal when it is loaded. Freezing was said to be infrequent and most usually occurs in movements to Thunder Bay. However, there are thaw sheds at Thunder Bay which were said to be very effective, so for movements in that direction freezing of the coal is not considered to be a serious problem although there is a cost involved.

There are no thaw sheds at the Vancouver terminals, but much fewer periods of low temperatures occur during movements in that direction. Furthermore, it was said that even then, freezing of the load does not usually occur if the loaded trip is completed in 38 to 40 hours and because the distance is only approximately 700 miles, the loaded trip is usually completed within that time frame. If the load does become frozen to the car sides, usually about 50% of it will discharge when the car is rotated for unloading, i.e., the "upper" portion will break away from the car side. In that circumstance, the train is put through the unloading track a second time, after it has been turned on the loop track. The other side of the car then becomes the "upper" side when the car is rotated and the remaining coal then usually falls out. Terminal costs are of course increased with that procedure.

It was generally the feeling of the mine representatives that the problem of freezing of the coal during transit, although troublesome at times, is not of sufficient concern to justify major expenditures to eliminate it. One industry representative did state, however, that in one instance his mine received an "empty" train that contained 800 tons of coal.

b) Compaction of coal around the drainage holes in the car floor

This problem was reported by the representative of only one of the mines and is caused by a combination of moisture in the car bottom near the drainage holes and the weight of the coal above. The compacted coal around the drainage holes does not release during unloading, particularly in cold temperatures. Efforts have been made by the railway to eliminate the problem by modifying the drainage holes, but with only partial success. It was said that the "carry back" is now running around one ton per car.

2.4 Environmental Requirement to Prevent Blow-Off of Coal Dust

Current practice is to spray the top of the load in each car before departure of the train from the loading site, using a liquid chemical which forms a tight seal to prevent blow-off. Industry representatives stated that environmental requirements are being satisfactorily met in this way. It was noted that the cost of the chemical is about $1000. per trainload or approximately $0.10 per ton of coal, but that on the basis of the findings in a 1982 study made by the Cambrian Engineering Group of Calgary on the comparative costs of chemical sprays vs covers on the cars[4], chemical spraying is the least costly. Nevertheless, the cost of the chemicals alone is a significant continuing cost burden to the mine operators, at least one of which shipped close to 9 million tons of coal in 1987.

2.5 Water in Empty Cars Placed for Loading

This problem too was reported by only one of the mine representatives. Obviously it is the result of blocked or otherwise non-functioning drainage holes. In effect, the water increases the tare weight of the car and inasmuch as the gross weight of the loaded car is limited to 263,000 lbs. (by weighing after loading), the amount of coal that can be put in the car is reduced. Nevertheless, the mine pays the railway on the basis of a full load of coal.

2.6 Non-Uniform Height of Cars

One mine representative stated that some empty trains include three different heights of cars, which causes delays in loading. Additionally, certain of the cars, apparently having been designed on the basis of a denser coal, will not hold a full 100 tons of their product, but the serving railway has adjusted its tariff to compensate for this.

2.7 Car Supply

One mine representative expressed concern that the railway serving his mine would not be able to supply sufficient unit trains if coal sales continue to grow. This railway has already had to lease some 300 cars from railways in the USA. Although the leased cars have a 100-ton load capacity, they are about six feet shorter than the Canadian cars. This initially caused delays in unloading at the west coast port. Adjustments have now been made at the port unloading facility to enable unloading the shorter cars with little or no delay.

The same company ships a considerable quantity of coal in less-than-unit train quantities to Manitoba Hydro and other customers. Cars supplied by the railway for these shipments are bottom-dump gondolas and are not always available in sufficient numbers. The railway has said it is not prepared to purchase additional cars. It seems likely that this is because the mine cannot guarantee a future requirement, in which case the railway position is understandable. Nevertheless, sales by the Canadian mine could be lost as a result.

2.8 Unloading Terminals

No major current problems at the west coast terminals nor at the Thunder Bay terminal were identified. As noted above, the difficulty initially encountered in unloading the shorter leased American cars (at the Roberts Bank facility of Westshore Terminals) has been overcome. An expansion program there has recently been completed, and further expansion is possible if necessary. Space requirements increase not only because of an increase in volume handled through the terminal, but also because of

increased numbers of types of coal, each of which has to be piled separately. One mine ships 18 different types of coal to Westshore.

3. RAIL TECHNOLOGY: STATE-OF-THE-ART

3.1. Introduction

As with other major industries, fundamental changes have taken place in the North American railway system over the past forty years. Early in that period, the steam locomotive disappeared fom the scene and was replaced with the cleaner and more efficient diesel-electrics. The general-purpose box car has been largely replaced by a variety of high-capacity special commodity vehicles, many of which are operated continuously in 100-car unit trains. The track structure has been greatly strengthened, train control systems have been improved and computer technology now pervades the industry. In the development and implementation of these and numerous other aspects of the railway revolution, Canadian railways have frequently led the way and are recognized world-wide as being in the forefront of present railway technology. A brief overview of the present state-of-the-art within the North American industry, particularly in Canada, is presented in the following.

3.2. Locomotives

As early as 1925, some diesel powered rail cars appeared in service on CN Canadian lines. In 1928 the first two diesel-electric road locomotives were acquired and in 1929 the first switcher. The 1928 road locomotives, which were combined freight/passenger units, were the first diesel-electric road units in North America and saw regular service until 1939 when they were re-engined and camouflaged to provide power for an armoured train. Following that service and a two-year period in passenger service, they were retired in 1946.(5)

The first significant purchases of diesel locomotives for Canadian service occurred in the late 1940's.The thermal efficiency of these diesel-electrics was about five times that of a steam locomotive and this benefit, along with much reduced maintenance requirements plus the opportunity to eliminate coal and watering stations on the right-of-way, resulted in the virtual elimination of the steam locomotive from the North American railway scene by 1960.

The early diesel-electric road locomotives were rated at 1000 to 1500 h.p. The introduction of the turbo-charger soon enabled doubling the maximum power and diesel-electric locomotives rated at 3000 h.p. appeared in the early 1960's. Other refinements resulted in further increases in power and as of the end of 1985, 1,178 of the total of 2,364 diesel-electric road freight locomotives in service in Canada (excluding Newfoundland) were 3000 h.p. or more.(6) In the order of 10% of these were 3600 h.p. This year (1988), 3800 h.p. and 4000 h.p. six-motor locomotives are being purchased by CN.

Locomotives in service on Canadian and other North American railways are a mixture of four-axle units (two 2-axle trucks with a total of four traction motors) and six-axle units (two 3-axle trucks with a total of six traction motors). At speeds over 23 mph a four-motor 3000 h.p. locomotive will develop the same tractive effort as a six-motor 3000 h.p. locomotive and since the train resistance of a four-motor locomotive is less than that of a six-motor locomotive, and the four-motor locomotives use less fuel(7), they are the favoured form of power except in cases where the necessary tractive effort cannot be generated economically because of low speeds due to steep grades, or where the horsepower per ton ratio of the train is too low.

Today's diesel-electric locomotives are far more efficient than were the first generation units of 30 years ago. This is particularly so with respect to the much greater load which they can haul up a steep grade at slow speed, made possible by the development of sophisiticated devices to prevent wheel slip. The initial such devices effectively increased the adhesion between the steel wheel and rail from 18% to 24% and recent versions provide up to 27% and even 30% in some operations.(8) Locomotives equipped with wheel slip devices generating 27% adhesion levels enable 50% more pulling (tractive) effort on steep grades than do locomotives without wheel slip devices, thereby significantly reducing horsepower requirements to negotiate the controlling grade on a trip. Such reduced horsepower requirements not only reduce fuel consumption but also reduce locomotive ownership requirements, particularly on a large system such as CN or CP. However, reducing horsepower on a train has the adverse

effect of reducing maximum achievable train speed on those portions of the route where maximum tractive effort is not required. This can lead to line capacity problems, the resolution of which is likely to more than offset savings generated by the increased tractive effort. Thus, increased adhesion levels with resultant increased tractive effort, although clearly beneficial for some operations, will not necessarily result in lower costs for others.

Numerous other developments in locomotive technology in recent years have further increased railway efficiency by reducing fuel consumption. Amongst these are improved turbochargers, larger diameter injectors, a higher compression ratio, lower engine idle speed, lower engine speed in dynamic braking, reduced cooling fan horsepower and two-speed cooling fans, reduced traction motor airflow and a higher efficiency alternator. Locomotives which embody these developments consume in the order of 10% less fuel than earlier models that do not.(9)

In other efforts to reduce fuel consumption, considerable work has been directed in recent years towards the development of devices to enable the automatic shutting down of idling locomotives. Idling occurs under several circumstances:

1. Locomotives are usually left idling when parked overnight or during other periods between assignments.
2. One or more of the locomotives in a multi-locomotive consist may be placed in idle during those portions of the trip in which the total power of the consist is not required.
3. Single locomotives in yard service are usually left idling when the locomotive is not working.

Possible difficulty in re-starting has been the principal reason for leaving locomotives idling. At low temperatures, there is also the possibility of engine freeze-up.

Devices to accommodate the first circumstance at all temperatures have been commercially available for some years and are in fairly widespread use in North America. Devices to accommodate circumstances numbers 2 and 3 have

recently appeared on the market and are in limited use. The ideal is a single device, or system, to automatically accommodate all three circumstances and developmental work is proceeding in that direction. When available, it has been predicted that such a device or system, installed on the total locomotive fleet of a railway, would reduce fuel consumption by as much as 10%.[10]

The high horsepower, more efficient locomotives of today enable greater tonnage to be hauled with fewer units. The consequent slowing in the escalation of railway ownership and maintenance costs has undoubtedly in turn slowed the escalation of tariffs, to the benefit of the national economy.

3.3. Freight Cars

The basic car fleet on Canada's two major railways consists of five types, i.e., box cars, gondola cars, hopper cars, tank cars and flat cars. Whereas in earlier decades the box car outnumbered all other types of cars combined, it now represents in the order of only forty percent of the Canadian rail car fleet.[2] This reflects the growing volume of bulk commodity and container/trailer traffic, for which gondolas, hoppers and flat cars are required. Between 1972 and 1985 for example, annual coal traffic on Canadian railways increased from 12.3 to 36.7 million tons.[11] Nevertheless, the box car remains an essential element of the car fleet, albeit a much different vehicle than the wood superstructure, 50 ft. 40-ton general purpose vehicle of the past. In the 1960's, demands for increased length and cubic capacity, particularly for automobile parts service, resulted in box cars with inside lengths of up to 86 1/2 ft. and capacities of up to 87 tons. Most box cars today, however, have inside lengths of 40 1/2 or 50 1/2 ft., with capacities of 60 to 80 tons, are of steel construction and have door openings, flooring and other characteristics designed for a particular type of lading.

Changes in the hopper, gondola and flat car fleets have also been dramatic. In the case of hoppers and gondolas, the most profound change has been an increase in carrying capacity from the earlier limit of 80 tons to 100 tons.

The so-called 100-ton "bathtub" gondola car designed by CP Rail, is an early outstanding example of this improvement. A parallel example is the 100-ton capacity cylindrical hopper car developed jointly by CN, CP and Transport Canada for grain service. Through the use of steel or aluminum alloys in the carbody construction, the tare weight of a car can be reduced, allowing an increase in the carrying capacity. Two recently developed aluminum cars have capacities of 110 and 107 tons respectively.[12] There are approximately 3,000 aluminum cars in the Canadian car fleet, but the bulk of these were acquired for grain service on secondary lines and those have a capacity of only 88 tons.

These major increases in carrying capacity per car have enabled the railways to keep the rate of growth in the numbers of such cars in the fleet to much below the rate of growth that would otherwise have been required to handle the significant increase in bulk commodity traffic that has occurred in recent years. As with the improvements in locomotives, this has undoubtedly slowed the escalation of tariffs to some extent.

Perhaps the greatest change in freight car design has been with respect to flat cars for container/trailer on flat car service (COFC/TOFC). Benefits of the new designs include reductions in line haul costs, in terminal loading and unloading costs, in maintenance costs and in vertical height when loaded. Characteristically, such new designs consist of lightweight platforms in lieu of the conventional flat car deck. In some designs the "car" length is extended by connecting several platforms together with semi-permanent drawbars permitting articulation between platforms for negotiating curves. Standard couplers are employed only on the outer ends of the end platforms. Frequently single-axle trucks are employed, rather than the usual two-axle truck. Overall, major weight savings are achieved by such innovations.

New designs include "single stack" and "double stack" types, the "double stack" type, as the name implies, being capable of carrying two containers, one above the other, the bottom one resting in a well in the platform so as to minimize the total vertical height above the rail.

3.4 Unit Trains

Unit trains provide the means to maximize the productivity gains that are possible through the increases in car capacity and locomotive power discussed in the preceding. A unit train service is one designed for the movement of a single commodity from one point of origin to one destination. Rolling stock operated in such a service is kept intact in train sets which shuttle in tightly controlled cycles between point of origin and delivery of the commodity being handled. Today, in Canada and other countries, coal, ore, grain, automobiles, containers and trailers are commonly handled in unit trains. In such service, car utilization is high and labour input low, with resulting low unit transportation cost.

Dedicated terminals are integral components of both bulk commodity and intermodal unit train services. Typically, in the case of bulk commodities such as coal or mineral ore, trains of 100 or more empty cars pass under a large storage silo into which the commodity being shipped has been elevated by conveyor and which is chuted into the cars as they pass under. A uniform train speed is automatically maintained by special controls which recognize the need for increased locomotive power as the train becomes heavier. By means of weigh-in-motion scales, the flow of material into each car is automatically cut off when the maximum permitted gross weight of the car is reached. At destination, trains are unloaded into an under-track hopper and conveyor system using rotary dumper equipment which physically rotates each individual car so that the contents are discharged downwards into the hopper out of the top of the car. Special couplers (rotary couplers) enable rotation of the car without uncoupling. Indexing equipment automatically maintains a uniform train speed during unloading.

Modern intermodal terminals feature high-capacity gantry cranes and fork lift trucks for the loading and unloading of containers and trailers. Gantry cranes typically span one or more tracks and adjacent paved areas, and are rail mounted to enable servicing a long cut of stationary cars.

Further increases in the efficiency of bulk commodity and intermodal unit train operations may result from an ongoing North American program directed

towards the development of a new generation of trains - the High Productivity Integral Train (HPIT). This program is discussed in Section 4.5.

3.5 Remote Locomotive Consists

An important technological development over the past two decades has been the use of locomotive units placed in the body of a train and radio-controlled by a locomotive engineer in the lead (control) consist at the head end of the train. The use of in-train locomotive units has a number of advantages of which the principal are:

- reduced drawbar loads, permitting heavier trains to negotiate steep gradients.
- shorter stopping distances due to faster brake responses throughout the train.
- reduced train shocks and therefore less equipment damage, due to faster and more uniform brake responses.

Reduced drawbar stresses result from the fact that the in-train locomotives are pushing as well as pulling. Their optimum position in the train is such that they push one-third and pull two-thirds of their rated load. With that configuration and operating method there is a point of zero stress (no compression and no tension) at the approximate mid-point of the train length. The maximum drawbar force (in the steady state condition) would be approximately 50 percent of what it would be if all locomotives were at the head end of a train consisting of the same number and weight of cars. The safe operation of heavier trains on steep grades thus becomes possible with consequent reduced operating costs. The reduction in equipment maintenance costs due to lower drawbar loads and reduced train shocks is an additional important factor in achieving the lower transportation costs typical of unit train operation.

The use of in-train locomotives is, of course, only beneficial if unit train operations are constrained by steep grades. In Canada, such is the case on CP's main line between Calgary and the Pacific Coast and on the Quebec North Shore and Labrador Railway (QNSL).

3.6 Train Control Systems

3.6.1 Early Systems

The basic objective of all train control systems is to ensure the safe and efficient movement of rail traffic from point of origin to destination. Early in the history of railways, trains were operated according to pre-arranged schedules or timetables which regulated their arrival and departure times with the objective of keeping trains apart by prescribed intervals of time, but the introduction of the telegraph in the 1850's enabled development of the train order system. This system, through written train orders authorized by a central dispatcher and delivered manually by the station agent to the crew of a train, gives exclusive possession of a specified portion or "block" of the route to a single train. This change, from the earlier time-interval basis for keeping trains apart to a space-interval basis, contributed significantly to both safety and efficiency of train operations.

3.6.2 Automatic Block Signal (ABS) System

ABS was first installed on Canadian railways during the 1940's. Basically, it is an augmentation of the train order system. In ABS territory, the main line is divided into a series of consecutive segments or blocks. Entry of a train into each block is governed by the aspect displayed by a fixed signal installation at the start of the block. These block signals are automatically controlled by the trains themselves. Presence or absence of a train is determined by an electrical circuit known as a track circuit, which, utilizing the rails as conductors, controls the aspect displayed by the block signal.

In territories where train density is high, ABS is an appreciably safer system of train control than is the train order system. Train delays are also reduced, and for these reasons, commencing in the early 1960's ABS was installed on most high density routes of the Canadian railway system. Although many miles of ABS have been replaced by Centralized Traffic Control, a total of more than 2,600 track miles of ABS still remain on Canada's two major railways.

3.6.3 Centralized Traffic Control (CTC) Systems

Essentially, CTC is a sophisticated version of ABS. Its principal advantage over ABS is the much greater number of trains that can be handled over a route in a given period of time, i.e., the much greater track capacity it provides. A single-track route equipped with CTC can handle approximately the same number of trains as a double-track route equipped with ABS. Inasmuch as installation of CTC is cheaper than construction of a second track, it is the logical choice when additional track capacity becomes necessary because of traffic increases.

The first installation of CTC in Canada was made in 1941 to enable handling the very large World War II-related traffic on the 124-mile route between Moncton, N.B. and Truro, N.S. Today there is a total of approximately 8000 track miles of CTC on Canada's two major railways.

CTC is a system of train operation by signal indication controlled from a central location. It places the control and operation of block signals and switches over an extended territory directly in the hands of the train dispatcher. CTC reduces the number of operators needed to run trains, directs trains entirely by signal indication, operates siding switches and crossovers electrically, and automatically informs the dispatcher by visual and audible indications of the location of all trains in the territory.

In CTC systems, safety checking resides at trackside where specialized control circuitry known as vital interlocking control ensures the fail-safety of the system by interconnecting the switches, signals and track conditions. Up until a few years ago, the fail-safe equipment consisted largely of electro-mechanical relays which were hardwired together in large equipment bays or racks. In recent years, microprocessor-based electronics have been incorporated into the vital interlocking control systems. With microprocessors, the functions of a hundred or more vital relays, and the hundreds of feet of interconnecting wires, can be combined into a few electronic cards. In addition to reduced space requirements, benefits from microprocessors include increased flexibility, reduced maintenance and lower costs.

New microprocessor and telecommunications technology now allow consolidation of many existing dispatching positions into large, regionally-based Central Dispatching Centres, a number of which have been installed in Canada.

Recent enhancements to CTC systems, also based on the availability of new microprocessor technology, include varying degrees of computer-aided dispatching. Computer-aided dispatching has been implemented at several major dispatching positions in Canada and incorporate a number of features not normally found on conventional CTC control machines. These enhancements include computer-aided control of signals and switches, train identification, misroute protection, electronic train sheets, and computer-aided protection of track maintenance activities.

3.6.4 Manual Block System

In the early 1960's, a method of train control known as the Manual Block System (MBS) was introduced on Canadian railways for application where low traffic levels do not warrant ABS or CTC installations. In MBS, radio rather than written train orders is used for the communication of formal movement instructions, or authorities, directly to train crews and track maintenance forces.

3.6.5 Computer-Assisted Manual Block System

Until recently there were more than 23,000 route miles in Canada operated with MBS, but on much of that mileage the railways are now implementing a new computer-assisted dispatching system. This system frees the dispatcher from many repetitive tasks, allowing for greater concentration on the effective planning and control of train movements. Known as Computer-Assisted Manual Block System, the system provides dispatchers with a video monitor to display the territory along with a highly improved communications console simplifying train movement operations. The system assists the dispatcher in the processing of MBS authorities, allows simple territorial assignment transfers, creates and updates the dispatcher's trainsheet, and permits direct electronic data exchange with trains, track maintenance forces, and other computer systems. The two major Canadian railways have implemented the Computer Assisted Manual Block System of train control on a

total of approximately 22,000 route miles including some former train order territory.

3.6.6 Future Train Control Systems

Notwithstanding the sophistication and integrity of existing train control systems, North American railroads are currently actively and cooperatively involved in the design and development of a new and specialized system known as the Advanced Train Control System (ATCS). ATCS will make the fullest use of the most recent advances in microprocessor and telecommunication technologies and will be immediately applicable to CTC, MBS or manually operated systems. ATCS will bring about the migration, to the central office, of safety functions that traditionally were located at trackside and the creation of a "smart" train, a train with locomotive-based microprocessor intelligence. ATCS represents the latest step in the evolution of train control and is expected to have a very significant positive impact on the efficiency and safety of train operations.

ATCS is modular in design and this will allow user railways to configure individual systems that provide the degree of simplicity or sophistication ideally suited to the particular territory under consideration. As needs change, compatibility between modules will allow systems to be upgraded from one level to another with a minimum of hardware replacement or operational disruption. The Computer Assisted Manual Block system referred to in the previous section is, in fact, an early to intermediate level of ATCS.

ATCS is described more fully in Section 4.12.

3.7 Railway Electrification

In 1975-76 a major study on the electrification of Canadian railways was carried out by the Canadian Institute of Guided Ground Transport.[13] Electrification was found to be technically feasible and would provide some operational savings. It would, however, require major capital investment and the payback period would be long. Overall, the potential net benefit to the railways was insufficient to encourage the major railways to move towards electrification, and the findings from a subsequent study of the

potential national economic benefits of conversion[14] were not enough to result in financial initiatives by federal government towards construction. Nevertheless, a series of research projects funded by Transport Canada were undertaken commencing early in the 1980's in order to obtain additional information on the technical problems and probable costs and benefits of railway electrification in Canada. Output from these projects greatly assisted B.C. Rail (BCR) in their decision to electrify their new 82-mile Tumbler Ridge Branch Line and contributed significantly to the design and expeditious construction of the line, which was placed in service late in 1983. It is the only electrified rail freight line in Canada and one of only three in the world having a 50 kV, 60 Hz power supply. Subsequently, the new 50 kV operation was extended southward on the BCR main line to Tacheeda, a distance of approximately 6 miles from the junction with the branch line.

3.8 Wayside Surveillance of Trains

The development, over the past 30 years, of equipment for the wayside surveillance of trains has been a major factor in increasing the safety of train operations. The initial impetus for the development was the need to identify, prior to failure, an overheated freight car bearing caused by lack of adequate lubrication in the waste-packed hand-lubricated journal box of the day. Although the incidence of overheated bearings has been greatly reduced through the development and widespread use, first of journal pad lubricators and subsequently of roller bearings, they still occur, and the hot box detector remains an important factor in minimizing train accidents. Today there is a total of approximately 500 of these devices installed on CP and CN main lines in Canada.

Hot box detectors are installed at 20 to 30 mile intervals depending on various conditions. The detection of overheated bearings is accomplished by heat-sensitive transducers mounted on each side of the track and placed such that they view the bearings as the train passes the site. These sensors produce an output that is proportional to the infra-red energy being emitted from the bearing being scanned.

A signal indicative of the heat energy from each bearing is then transmitted to a central office, where the data are interpreted by a skilled operator who in turn advises the train crew by radio as to which car and bearing is suspect. Alternatively, the processed heat signal may be reported directly to the train crew - either by a wayside "scoreboard" displaying an axle-count to the rear of the train from the suspect bearing, or by a voice synthesizer unit or "talker" reporting over the train radio.

Recent enhancements to hot box detector systems include: improved sensor optics, advanced digital data transmission replacing error-prone analog transmission, improved bearing heat signal processing, and improved train speed monitoring functions. Microprocessors are also being used in the dispatching office to assist the hot box detector operator to more accurately analyze hot box detector tapes, and to permit communication with other railway computer systems.

The continuous monitoring of bearing temperatures using on-board equipment would presumably be superior to the current wayside monitoring system which is by nature intermittant. In fact, on-board hot box detection equipment is standard on modern passenger train equipment but although much effort has been made towards development of a satisfactory on-board system for freight trains, wayside systems remain the most reliable and economic.

In recent years the scope of wayside detection devices has been expanded beyond merely the detection of hot bearings. Overheated wheels caused by stuck brakes, out-of-round wheels, dragging equipment, overloaded cars and shifted loads are all potential causes of train accidents and are all detectable by wayside devices now available and in use by the industry.

3.9 Computer Technology

Railways were one of the first major industries to enter the computer age, with the use of data processing equipment for the handling of their inherently large volumes of accounting and financial data. In the intervening years railways have been, and remain, on the leading edge of the shift towards the widespread use of computer technology to improve

operational and managerial effectiveness and productivity.

Computer-based information systems now in place on major Canadian and other North American railways provide real-time data on movement and status of all cars on line and a wide variety of other data to satisfy management needs for effective operational control of the railway. These and other computer-derived data, in combination with modern communications facilities and the widespread use of PC's, also enable immediate response to a shipper's call to a customer service centre as to location and status of his shipment, train schedules, placement of empty cars at his plant, rates and/or other shipping information. One of the more recent enhancements to customer information services on some railways is a computer-to-computer link between the customer and the railway for the supply of certain types of information.

Undoubtedly the greatest impact of computer-based technology on the railway industry has been the vastly improved ability to manage an extremely complex and often geographically widespread business enterprise more effectively and efficiently. However, the application of that technology has not been limited to managerial techniques. It has permeated all of the many vital technial activities required to support operations, with resulting major improvements in productivity and safety. Some of the more significant of these applications are noted in the following:

- Microprocessor controls for locomotives and track maintenance machinery
- On-board monitoring of locomotive engine performance and significant train operation parameters
- Simulators for the training of locomotive engineers
- Simulation programs for studies of longitudinal train action and control, and for performance of individual cars or locomotives and/or components thereof
- Train control systems
- Measuring track geometry quality, rail wear, rail loads
- Design of structures, car and locomotive components
- Preparation of engineering drawings

- Compilation and constant updating of:
    - track, signals and equipment inventory and condition
    - work plans and budgets
    - stores stock
- Operation of freight car classification yards and of terminals for the loading and unloading of bulk commodities

3.10 Track

The rapid increase in the numbers of 263,000 lb. gross weight freight cars and higher-horsepower heavier locomotives, which appeared on railways during the 1960's and 70's, quickly resulted in a requirement for a stronger track structure to reduce replacement and maintenance costs. At the same time, escalating labour costs compelled reductions in manpower for both maintenance and construction.

To strengthen the track structure on heavy traffic main lines a number of major steps have been taken. The 100 or 115 lb. (per yard) rail in 39 ft. lengths has been replaced with 132 or 136 lb. continuously welded rail (CWR). Alloy and/or heat-treated rail is used in curves to reduce wear. The depth and width of the ballast section has been increased and ballast quality has been improved. Geotechnical fabrics are employed to improve track drainage and prevent contamination of the ballast. In heavy traffic territories all-welded turnouts are used. As is discussed in Section 4.9, some railroads are replacing wood ties with concrete ties in curves to provide a more rigid track structure and a superior connection between the rail and the tie.

The formerly labour-intensive tasks of track maintenance and rehabilitation are now accomplished by a much smaller work force and a large inventory of machinery specifically designed for the work. The inventory includes microprocessor-controlled tamping and lining machines, machines for replacing ties, cleaning ballast and a multitude of other types. In use on some railways is a track renewal train which picks up wood ties, installs concrete ties and lays new continuous welded rail all in one operation.

Sophisticated inspection cars to monitor track quality to carry today's

longer and heavier trains are now in common use. Rail integrity is monitored regularly by one type of such equipment for the detection, by means of ultrasonic devices, of internal defects which might result in early rail failure. Rails found to have such defects are replaced immediately.

Another type of such equipment is employed for monitoring, analyzing and recording important track parameters such as surface profile, gauge, curvature, superelevation and track twist. Equipment to accomplish this is housed in a rail vehicle, usually a converted passenger coach, which is hauled in a train, but in some cases, in a self-powered rail vehicle. Most of these monitoring vehicles are capable of making accurate measurements at high speeds, some in excess of 100 mph. Various technololgies such as laser and infra-red sensors, are employed for track quality measurement. Information from the sensors is fed to on-board computers which process it to produce reports in real-time. These reports are designed and employed for various purposes such as immediate corrective track maintenance and annual and long-term maintenance planning and budgeting.

4. ONGOING TECHNOLOGICAL DEVELOPMENTS AND RESEARCH

4.1. Introduction

Over the past two decades, major efforts within the North American railway industry and supporting research and development organizations have been directed towards the further reduction of railway operating costs through technological development. As discussed in Section 3, new locomotive and freight car designs, widespread use of computer technology and much improved track quality are amongst the advances already made. Efforts are continuing to further reduce costs and some of the most promising of these are discussed in this section.

4.2 Radial Axle Trucks

Soon after the introduction of high-horsepower locomotives equipped with 3-axle trucks, evidence of high lateral curving forces manifested itself by way of excessive rail and wheel wear, and in some cases, rail overturning. Investigations of cause led to reductions in these damaging forces through improved locomotive truck design and modified wheel profiles, with consequent reductions in track damage.

The increasing proliferation of 100-ton capacity freight cars in the early 1970's also led to much increased rail wear in curves as a result of high lateral forces. Investigations by both CN and CP directed towards reduction of these forces led to the development of modified freight car wheel profiles (higher conicity). In a series of tests carried out in 1976 on CN gondola cars with standard trucks in coal service, it was found that the average wheel life to first turning was extended by approximately 75% through use of higher conicity wheels[15] and they are now used by both major railways on cars in bulk commodity unit train service.

Another outcome of the investigations was development of the so-called radial axle trucks. Common to the several such trucks developed, are modifications to resist those forces which result in a high angle of attack of the leading wheelset on the outer rail in curves. Commencing in the late 1970's, both CN and CP carried out extensive testing of these types of

trucks to evaluate their benefit in reducing wheel wear, with very encouraging results.[16] In order to accumulate sufficient mileage on the trucks to provide conclusive evidence of their economic benefit over the long term, one of the CP tests is still in progress. In that test, five carsets of each of the two most promising of the radial axle type trucks were placed in revenue service in 1982 in order to determine their benefit by comparing them with trucks on control cars equipped with conventional trucks in identical service. The most recent published report on that work gives the findings after one of the truck types being evaluated had accumulated 250,000 miles and the other type 130,000 miles. The findings show that flange wear on the wheels of the radial axle trucks was only 20% of that on the wheels of the conventional trucks and tread wear was only about 66%.[17]

It is evident that because of the reduced curving forces inherent with radial axle trucks, rail wear will also be less than with conventional trucks. Likewise, fuel consumption should be less, although such fuel savings will be at least partially offset because of the greater weight of the radial axle truck as compared to a conventional truck. As yet, however, there are no reliable quantitative data on these two factors.

An additional important benefit of the radial axle truck is that self-excited oscillation of the truck (hunting) on tangent track is controlled. With conventional trucks, this hunting, which is normally most severe under an empty car, may be of sufficient severity to cause derailment. Although hunting is not completely eliminated on radial axle trucks, the speed at which it first commences is significantly raised, thus enabling the safe return movement of empty unit trains at higher speeds with consequent increased productivity of the equipment.

Despite the apparent superiority of radial axle trucks over conventional trucks, their higher initial cost can only be economically justified under certain circumstances, such as under heavily loaded cars operating over track with a high density of curves.[18]

There are currently eight unit trains equipped with radial trucks operating

in revenue service in Canada. They consist of of one CP coal train and seven CN/BCR trains, these trains having a combined total of more than 800 cars and more than 1600 radial axle trucks. Each company is continuing to monitor the performance of their trucks.

4.3 Reduction in Freight Car Weight

The early 263,000 lb. gross weight North American bulk commodity car had a tare weight of 31.5 tons and a payload of 100 tons. The tare weight can be, and has been, reduced and the payload correspondingly increased through the use of high strength steel, aluminum, or other material such as fiberglass reinforced polyester in the carbody construction. In the case of aluminum for example, cars when designed for equal strength will weigh less than conventional steel cars by as much as 20 to 30 percent. The corresponding possible increase in payload, which can be in the order of 7 to 10%[12] while still maintaining the 263,000 gross weight track loading limitation, can result in appreciably fewer gross ton miles, train miles, locomotive miles and car miles if the lighter cars are employed in regular unit train service. The resultant operating cost savings can be substantial. New designs to maximimize such savings continue to be developed and purchases of aluminum cars by American railways are increasing.

However, such operating savings will be at least partially offset by the higher initial cost of aluminum compared to steel. Care must therefore be taken in design to avoid the overuse of aluminum, yet still achieve sufficient weight reduction to produce the necessary net benefit in the trade-off between reduced line haul costs and higher car purchase costs.

Design is also critical from the standpoint of minimizing car maintenance costs. Although aluminum has superior resistance to corrosion than does steel (which would suggest lower car maintenance costs), higher maintenance costs might in fact be the case because of the lower fatigue strength of aluminum compared to steel. Judicious design must therefore be employed to avoid a high level of fatigue failures in the aluminum components five to ten years after the cars have been placed in service.

4.4 Slackless Drawbars

Conventionally, the coupling system between freight cars has included shock absorbing devices (draft gear) designed to receive coupler forces and dissipate them without damage to the car structure or lading. The draft gear is fitted within a pocket at the end of the car and is connected to the inner end of the coupler shaft by a yoke. The inner end of the draft gear bears against draft lugs which are rivetted or welded to the centre sill of the car.

In its early form, the draft gear consisted of heavy coiled springs; however, these have been displaced by more sophisticated energy-absorbing devices. Standard draft gear systems usually permit a total coupler travel of about 5 1/2 inches in either draft (pull) or buff (compression) but travel may be as much as 9 1/2 inches with some types. So-called "cushion" cars are equipped with draft gear permitting up to 15 or 30 inches of coupler travel depending on the type of system employed.

In long trains, especially those consisting of loaded 100-ton bulk commodity cars, the "slack" action permitted by even standard draft gear can result in very high coupler forces, particularly in undulating territory. Such forces can result in damage to track or equipment and even derailment. Efforts to minimize such occurrences, and at the same time facilitate the handling of long trains, has led to the concept of an inter-car connector totally free of slack. This concept has recently been realized in the development and testing of so-called slackless drawbars.

Although theoretically all cars in a train could be equipped with slackless drawbars, railway operating considerations suggest blocks of only 5 or 10 such cars, with the outer end of the first and last cars in each block being equipped with standard couplers and draft gear. Various concepts of such trains have been proposed and some tested in revenue service. On the Norfolk Southern railroad, for example, a 14,300-ton train, made up of 4 locomotives and 10 blocks of 10 slackless drawbar 100-ton cars has been in revenue coal service between southern Indiana and northern Georgia for approximately one year as of the time of writing. Measurements made show

maximum in-train forces to be only 20% of those occurring in a similar train comprised of cars equipped with standard couplers and draft gear operating on the same route.[19]

An important secondary benefit from replacement of the conventional coupler and draft gear with slackless drawbars is weight reduction. The net direct saving because the slackless drawbar is lighter, is in the order of 1,500 lb. per car. Additionally, it is probable that the reduced slack action in the train and consequent much reduced in-train forces will enable re-design of the centre sill with further weight savings. Furthermore, the reduced slack action will enable satisfactory control of the train with simplified air brake control valves, which, although not contributing to weight reduction, would slightly reduce both purchase and maintenance costs.

4.5 High Productivity Integral Train

The High Productivity Integral Train (HPIT) can be defined as an advanced technology unit train, the components of which do not have to meet all of the AAR interchange requirements. For example, if the cars in the train are to remain on one railway only, i.e., not interchanged, and will not be put through a classification yard, they need not comply with the AAR specifications for resistance to impact.

HPIT development was initiated by the AAR in 1984 through a request to the North American railway supply industry for expressions of interest in a program to promote the development of such trains. In response, proposals for thirteen different train systems were received; eight intermodal (transport of trailers or containers) and five bulk commodity. Over the past three years, extensive technical and economic review of each proposed system has been conducted by the AAR. Current status of the developments vary from still incomplete design through prototype construction and testing of components, to revenue demonstration service.

Each proposed system includes features to increase productivity and reduce cost.[19] Emphasis is placed on weight reduction and to that end, several of the intermodal designs employ long articulated platforms in

lieu of the conventional flat car and one employs double stack container cars (these features are described in Section 3.3). Single axle trucks are employed in some cases. In two of the trailer train designs, the trailer itself serves as the car, with the two adjacent trailer ends being supported on a single two-axle railway truck. A third train design employs special trailers as cars, each with two widely spaced axles equipped with rubber-tyred wheels at one end, between which is a third axle equipped with flanged wheels. When on the rails, the highway axles are retracted and the non-wheeled end of the trailer is supported on the wheeled end of the adjacent trailer. On the highway,the rail axle is retracted.

In the bulk commodity train designs, slackless drawbars and light-weight aluminum cars are featured and radial axle trucks and radio controlled remote locomotive consists are also included. One design includes a conveyor system for self unloading of the eleven 95-ton capacity hopper cars in the consist.

Other innovations directed towards increasing productivity, in addition to those mentioned above, are included in the various intermodal and bulk commodity HPIT designs. Although it is not expected that all of the proposed systems will come to fruition, it appears on the basis of analysis and testing carried out in the USA to date, that some positive impacts on productivity and costs will result from the program.

4.6 Reducing Train Resistance

4.6.1 Improving Aerodynamic Qualities

The importance of minimizing aerodynamic drag to reduce fuel consumption and improve the handling qualities of high speed vehicles has long been recognized. To obtain data on the extent of fuel savings that might be achieved through a reduction in aerodynamic drag on bulk commodity unit trains, wind tunnel tests were conducted by the AAR in 1984 and 1985 using scale models of typical coal-carrying gondola and hopper cars and two types of high-horsepower locomotives.[20] Tests were made of the scale equipment in its normal configuration and with variations from normal, such as with and without covers on the cars, side stakes on the outside of the

car (normal) and side stakes on the inside, various lengths of cars, various spacing between cars, cars loaded and unloaded, various components partially streamlined, etc.

It was found that aerodynamic drag is reduced by:

- Covering the car
- Smoothing the car sides
- Rounding off corners and closing gaps
- Adding airfoils over the car ends

Using computer simulation models, runs were made of trains consisting of four SD40 locomotives and one hundred 101-ton cars, to ascertain the potential fuel savings from improved aerodynamics. The runs were almost 350 miles each way between a mine and a power plant in the fairly level midwestern United States. Five different trains were compared, each consisting of a different type of car as follows:

- Standard rotary-dump gondola, no covers
- Standard rotary-dump gondola, flat covers
- Streamlined gondola, no covers
- Fast discharge hopper, no covers
- Fast discharge hopper, flat covers

In the case of the gondola car train simulations, the addition of flat covers on the cars reduced the fuel consumption for the round trip by approximately 1500 gals. (US) or 13%, almost all of this reduction being achieved on the empty return trip. The addition of streamlining reduced the consumption by approximately 700 gals. (US) or 7% compared to the no cover gondola case.

For the hopper car train simulations, the addition of covers reduced the fuel consumption for the round trip by approximately 900 gals. (US) or 8%. Again, almost all of this reduction was achieved on the return trip.

4.6.2 Rail Lubrication

The application of lubricant to the gauge face of rail in curves to reduce

wheel and rail wear has been standard practice on most major North American railways for many years. Rail/wheel lubrication also reduces train resistance, and the consequent potential for fuel savings through gauge face lubrication in tangent track has resulted in a number of tests and studies by the AAR and various railways in the USA. Methods for application of the lubricant include specially equipped hi-rail vehicles, locomotives and modified box cars.

The percentage fuel savings will vary widely, depending on the amount of curvature and gradient. Extensive tests on Conrail over various types of territories, i.e., severe gradients and curves, moderate gradients and curves and mild gradients and curves, gave the following results:[21]

Territory	Savings (Fuel)
Severe	0.5%
Moderate	5.2%
Mild	11.0%

By classifying the bulk of Conrail's main line roughly into the three categories, it was estimated that a system composite fuel saving of 7.3% could conceivably be obtained through rail lubrication.

During a five-month test in 1985 on a 230-mile corridor on the C&NW railroad, on which a mix of manifest trains, unit coal trains and empty hopper trains is operated, it was found that rail lubrication resulted in a net reduction in fuel consumption for loaded trains of 9.2% to 9.8% and 15.5% for empty hopper trains.[21]

These and other findings have established that a significant reduction in fuel consumption can result from continuous rail lubrication from a moving vehicle to supplement the long-standing practice of curve lubrication only by means of trackside lubricators. Several different lubrication systems for installation on locomotive or other rail vehicles are now available and evaluation of these, for their own use, is in progress on various railways.

4.7 AC Traction

Increased productivity and reliability of diesel-electric locomotives and

significant reductions in maintenance costs are possible through utilization of AC traction motors in place of the DC motors which historically have been employed with North American diesel locomotives. Although the technology to enable this is well understood, and has been applied elsewhere, the size and weight of the circuitry to accomplish it have previously prevented its economic application in Canada and the USA. However, technological developments over the past decade, particularly in the field of the silicon controlled diode (SCR) or "thyrister" control, have substantially increased the technical and economic feasibility of AC traction for North American application, and considerable activity directed to performance evaluation of the system is underway.

In that respect, Canadian Pacific fitted a 4000 h.p. freight diesel with thyrister converters in 1985 to provide 4 - 1000 h.p. AC powered axles.[22] The planned two-year revenue service test program of the converted unit is expected to be completed in 1988 and performance of the basic equipment to date has confirmed expectations. In the USA, Amtrak has recently completed conversion of one of their 3000 h.p. diesel electrics built in 1956, and it is currently undergoing tests. Also in 1988, Amtrak ordered two new 3000 h.p. AC locomotives. Transit authorities in the USA have recently converted several DC locomotives to AC and have purchased cars equipped with AC propulsion systems.

It appears likely that conversion to AC traction will be the next major change to the North American railway industry's locomotive fleet. However, because of the high cost of such a change, more evidence that the potential economic benefits can indeed be achieved will first be required by the industry. The change is therefore unlikely to take place quickly.

4.8 Rail Profile Grinding

Rail damage in curves on portions of Canadian and American railways increased dramatically in the 1970's with the growth of unit trains comprised of 100-ton cars. To counteract this, the use of alloy and/or heat treated rail was increased, heavier rail was installed, greater emphasis was placed on the proper functioning of rail gauge face lubricators, tie quality

was improved and the ballast section was strengthened. Neverthless, rail damage in curves with consequent need for replacement has continued to be a significant cost burden.

Although lubrication of the gauge face of the rail in curves reduces the rate of gauge face wear, it contaminates the rail's top surface and brings about the initiation and growth of contact fatigue cracks which develop into head checks, shelly spots and flakes and causes corrugation of the rail. Nevertheless, providing the corrugations are removed periodically by grinding (using a special train equipped with as many as 120 grinding wheels), a longer rail life can be achieved with gauge face lubrication than without it. On heavy traffic lines with a high density of curved track, it may be necessary to grind the rail as often as every four months to prevent corrugation from exceeding the specified maximum depth, typically in the order of 0.02" depending on the particular railway's practice. Inasmuch as considerable metal is removed with each grinding, the life of the rail in track would be prolonged if the frequency of grinding could be reduced through a reduction in the rate of growth of corrugations.

Considerable success has been achieved to that end through a process known as rail profile grinding. It consists of utilizing the rail grinding train to modify the cross-sectional profile of the head of the rail in order to change the geometry of the rail/wheel contact. This results in a reduction to the very high contact stresses which occur at critical points on the rail head, thereby decreasing the rate of corrugation growth. The balance desired by the railway, between control of gauge face wear versus control of corrugation and shelling, will influence the design of the ground profile of the rail head, as will also other factors such as degree of track curvature, condition of wheels and amount of dynamic gauge widening, all of which may vary slightly from railway to railway. The optimum profile, therefore, tends to be specific to a particular railway or even to a particular location on the railway.

Although carefully conducted rail profile grinding will reduce the rate of growth of corrugation and extend rail life, it will not in itself eliminate the formation of corrugations. In the absence of other action, the

corrugations will grow and must ultimately be removed by grinding just as in the past (corrective grinding). However, recent laboratory research and analysis has shown that by combining rail profile grinding with more frequent and lighter grinding cycles (preventive grinding), the formation of corrugations can be prevented. It is estimated that this combined procedure, as compared to the past procedure of corrective grinding only, will result in up to a threefold increase in rail life, assuming that the rail in both cases were to be removed from track solely because of loss of section due to grinding.[23]

Both CN and CP have recently implemented rail profile grinding on their high density lines, followed by preventive grinding to the extent possible. This practice has as yet been implemented on only a few American railroads and hence little statistical data are available regarding actual prolongation of rail life that is being achieved. It is already apparent though, from the Canadian experience, that the life of rail in well-lubricated curves in tracks carrying in the order of 30 million tons per year or more can be extended significantly through its use.[24,25]

4.9 Concrete Track Ties

Historically, in Canada and most parts of the USA there has been an abundant supply of good quality timber for the manufacture of track ties at low cost. In recent years, the reduced availability of hardwood and even good quality softwood has impacted adversely on tie quality and price and led to a growing interest in concrete ties. However, uncertainty as to whether their service life will be sufficiently longer than that of wood ties to justify their higher initial cost has so far discouraged acceptance by all but a few North American Railways. Nevertheless, significant numbers of concrete ties have been, and continue to be, installed annually.

Canadian National, a major user of concrete ties, commenced installing them in curves on high-tonnage track in the early 1970's, and now has more than 3 million in track. As part of their new Rogers Pass tunnel project now nearing completion in the Canadian Rockies, CP Rail has installed more than 27,000 concrete ties. CP also has a number of test installations in place

in existing track. In the USA, Amtrak has installed concrete ties in their northeast corridor track commencing in the early 1980's. Extensive installations have also been made by the Kansas City Southern, the Florida East Coast and the Burlington Northern railroads.

Two important benefits are provided through the use of concrete ties in place of wood ties. The first is the large increase in track modulus (greater track stiffness) which results from their greater weight. The second is the improved rail fastening systems available for use (compared to the dog spike usually used with wood ties). A higher track modulus and an improved rail fastening system contribute to better track surface and alignment and to improved retention of track gauge. This results in a reduction in track and equipment maintenance costs and in a reduction in the risk of derailments with their high costs in terms of both dollars and service reliability.

A spin-off benefit from the higher track modulus provided by concrete track ties is reduced fuel consumption due to the reduced train resistance. Fuel savings are estimated to fall in the 2 to 4% range.[26]

4.10 Rear-of-Train Telemetry

Technology has been developed in the form of rear-of-train equipment which enables elimination of the caboose from freight trains. This equipment collects the data necessary for safe train operation (formerly monitored by the crew in the caboose) by means of an electronic device located on the trailing end of the train's last car, and sends the data by radio to receiving and display equipment in the locomotive cab.[27] The equipment also enables emergency brake application to be initiated at the rear of the train by a radio signal from the locomotive cab. Replacement of the caboose with rear-of-train equipment will be appropriate for all road trains except for general freight trains required to make frequent pick-ups and set-outs at customer plants. Significant savings in caboose ownership and maintenance costs, with no reduction in safety, will therefore result.

Rear-of-train telemetry equipment has been in operational service in the USA

since 1984 and in December of 1987 was approved by the Canadian Transport Commission for service in Canada.

4.11 Locomotive Event Recorders

On-board systems to monitor the operation of locomotives, which can be likened to the back boxes utilized in the aircraft industry, are being increasingly used by North American railways. Commonly they are referred to as event recorders, a term applied to earlier versions of such systems and which first became commercially available in the mid 1970's. With few exceptions the capability of these early systems was limited to the monitoring of important train handling parameters such as changes in speed, throttle position, brake pipe pressure and dynamic brake setting, application of emergency brake and use of locomotive horn. Each of these "events" were related to the precise location of the train at the time of its occurrence. Advances in technology over the past decade have enabled manufacturers to not only improve the reliability of the systems, but to also expand their capabilities to include the monitoring of important indicators of engine performance. Additionally, the inclusion of capabilities related to the Advanced Train Control System (see Section 4.12), to avoid future duplication of hardware, are being explored. The potential benefits of the system are therefore becoming more attractive to the railway industry.

Like the aircraft black boxes, event recorders can play a valuable role in post-accident investigations by assisting investigators in reconstructing events immediately prior to an accident. Additionally, the data collected by the recorder can be downloaded into a portable computer by a supervisor immediately following a trip, and the train handling during the trip discussed with the train crews with a view to improving performance. Similarly, the devices can be useful in the training and qualification of candidate locomotive engineers. The information collected on engine performance can be utilized by maintenance personnel in preventive maintenance activities.[28] Both major Canadian railways are currently engaged in equipping their road locomotive fleet with recorders to improve safety, training and locomotive maintenance procedures.

4.12 Advanced Train Control System (ATCS)

At present, the state-of-the-art in North American railway signalling and train control systems is represented by the ABS and CTC systems which are discussed in Section 3.6 of this report. However, for some time it has been recognized that a more economic, more comprehensive and safer next generation train movement control system based on microprocessor and mobile data communications technology is possible. Under the leadership of a committee comprised of representatives of the Canadian and US railways and supplier industry, the development of such a system, known as the Advanced Train Control System (ATCS), is essentially complete. The system has already been partially implemented on CN, CP and the BCR.

4.12.1 Description of ATCS[29]

ATCS is modular in design and this will allow user railways to configure individual systems that provide the degree of simplicity or sophistication ideally suited to their scale of operation or to the particular territory under consideration. Systems may range from the relatively simple to the very complex and, as needs change, compatibility between modules will allow systems to be upgraded from one level to another with a minimum of hardware replacement or operational disruption.

Consistent with this approach, ATCS has four distinct "levels". These are:

- Level 10, Centralized Route and Block Interlocking System
- Level 20, Automated Transmission and Display of Instructions
- Level 30, Full Train Tracking
- Level 40, Full Field Interlocking

Progression from one basic level to the next is accomplished by adding key capabilities, each of which permits the introduction of a number of new features and options. Divisions of ten were chosen for the level numbering system because at any level many options are available. For example, a Level 30 system may include only a few of the available options (a Level 31 system), or virtually all of them (a Level 39 system).

Level 10: Centralized Route and Block Interlocking System

At this level, ATCS is a very elementary system, basically a centralized route and block interlocking system; however, it forms the foundation for ATCS and is intended for application in territory presently controlled manually. Microprocessor-based equipment at the dispatcher's work station will provide interlocking logic to prevent overlapping authorities from being issued. Communications between the dispatcher and train, or track forces, is by voice radio. No options are available to enhance the basic package, nor are there any on-board elements.

Level 20: Automated Transmission and Display of Instructions

The next level adds a vital data communications link and microprocessor-based equipment on locomotives and selected maintenance-of-way equipment, thus providing two-way data communication between the dispatcher and trains or other mobile equipment. The vital data link is the principal means of communicating movement authorities.

This stage does not include automatic tracking of trains, and locomotive engineers would report clear of authority limits by voice radio, or by initiating an appropriate data message. All communications between track forces and train crews could remain verbal at this level.

Introduction of the data communication link and mobile display terminals permits a number of options to be added to the basic package with relatively minor hardware or software additions. These options include vital data communications between the central dispatching computer and track forces to provide automatic receipt of train line-ups, automatic application of temporary slow order and, subject to override by the central computer, automatic receipt of track occupancy permits and application of unplanned work blocks.

Other options could include on-board sensors for monitoring and diagnosing locomotive condition, status monitoring of wayside equipment, on-board display of defective equipment detector reports, and a form of switch control short of full field interlocking. This level might also include

some level of track structure integrity protection, but significant new research will be required to develop such capability fully.

Level 30: Full Train Tracking

This level introduces an automatic location and identification system to keep track of train location and identity. In addition, it might be used to locate and monitor maintenance-of-way equipment. This ability for the control system to continually monitor train location and identity, and for the train itself to continually know "where it is" makes possible a number of features. A key one will allow the train to report clear of authority limits automatically.

Other options which could be incorporated are:

- On-board display of current allowable speed, next allowable speed, and distance to next allowable speed zone.
- Automatic reactive or predictive braking to enforce speed or authority limits. For "predictive" enforcement of authorities, it would be necessary to download route characteristics data to the on-board computer.
- On-board route characteristics display, which might be integrated with the display of allowable speed and authority information, and other data to assist in safe and efficient train handling.
- A locomotive security system.
- Progressive display of slow order and work block information.
- Automatic conflict resolution and projection of train paths by the central computer.

5. DISCUSSION

5.1 General

Generally, the specific rail transportation problems identified by the mine representatives are not fundamental faults in the system. This is not intended to imply that they are inconsequential, for unquestionably they all impair the efficiency of the system with resulting cost increases, mostly to the mine operators. It is obvious though, that their correction is a matter of adjustments to the system rather than its re-design

It was stated by most of the coal company's representatives that there is good cooperation between the producers and the railways. However, it has not as yet enabled resolution of those problems mentioned by the representatives which only the railway company involved can rectify, i.e., late delivery of empty trains for loading, non-uniform heights of cars and non-functioning drains in some of the cars.

With respect to the problem of freezing of coal during transit, the Department of Energy Mines and Resources Canada, through the Coal Research Laboratories of CANMET, has awarded a contract to carry out a review of the state-of-the-art in coal freezing in railway cars and the development of a proposed program of applied research directed to controlling the problem. It is expected that the work will be completed in 1988.

As to the concerns expressed by the producers with respect to the high proportion of their total costs attributable to transportation, most of the ongoing technological developments discussed in Section 4 hold promise for future reductions in railway operating costs, which should serve to at least partially offset the effects of inflation on coal tariffs. Slackless drawbars in particular appear to have appreciable potential for reducing operating costs, and on the basis of the work done by the AAR on aerodynamic drag, direct benefits to the coal industry may be possible through the use of covers on the coal cars. However, in both cases work is needed to verify these possibilities. The rationale for such work is discussed in Sections 5.2 and 5.3.

To bring about a reduction in tariffs, a very large gain in transport productivity would obviously be needed. One possible potential for such a gain may be the bulk commodity High Productivity Integral Train developments now well underway in the USA and discussed in Section 4.5. In that same area of development, a major gain in productivity might ultimately result from a more recent study, commissioned by the Alberta Economic Transportation Services Branch. Its specific purpose was to find ways to substantially improve the net load of unit trains moving Western coal to Ontario markets, and was carried out by National Steel Car of Hamilton, Ontario. In the report on that study, "High Efficiency Coal Car for Unit Train Service" dated March, 1987[30], it is stated that "a special coal car can be constructed, using technology, to improve the net train load by more than 38% over present coal trains without exceeding acceptable axle load, bridge load, or dimensional limitations". The present status of this development is not known, but on the surface at least, it would seem to be worth pursuing.

5.2 Fuel Savings Through the Use of Covers on Coal Cars

As was noted in Section 2.4 of this report, the current method employed by the Canadian coal producers to prevent coal dust blow-off during the trip from the mine to the unloading terminal, is to spray the top of the load in each car with a liquid chemical immediately following loading of the car. This was said to be less costly than controlling the blow-off through the use of covers on the cars and reference was made to a 1982 study made by the Cambrian Engineering Group.[4]

In the Cambrian Engineering study, which has since been reviewed, one of the two hypothetical cases examined was a unit train movement of ten million tonnes of coal (eleven million tons) per year from a mine in S.E. British Columbia to a terminal in Vancouver, an assumed distance of 1100 km or 662 miles. (It is actually close to 725 miles). A chemical spray system was assumed to be in place, which would make that case similar to the present real-life situation. The three alternatives of continuing the use of chemical spraying, the use of hinged steel covers and the use of fibreglass lift-off covers were each costed and the total costs, expressed in terms of cost per tonne of coal transported, were calculated to be:

Chemical spraying	38 cents/tonne	(34 cents/ton)
Hinged steel covers	80 " / "	(73 " / ")
Fibreglass lift-off covers	44 " / "	(40 " / ")

Provision was made in the cost estimates for all foreseeable costs as applicable, such as the cost of the covers and the cover handling system, installation of covers, maintenance of the covers and of the overall system. The loss in car capacity because of the weight of the covers was also included. In the case of the steel hinged cover system, provision was also made for necessary modifications to the mine loading facilities and for additional maintenance cost due to inability to turn the cars because the cover hinge must always be on the same side of the car. For the chemical spray system, nil capital cost was charged because the scenario assumed the system to be in place. A 0.15% product loss was charged to the spray system as was also the cost of the chemical.

No provision was made in the cost estimates though, for fuel savings that would result from the use of covers, as was found to be the case in the AAR investigations regarding aerodynamic drag. As is described more fully in Section 6.1, in simulations made as part of those investigations, of a train made up of locomotives and one hundred 101-ton gondola coal cars on a run of 350 miles each way between a mine and a power plant in the fairly level midwestern United States, it was found that the addition of flat covers on the cars reduced the fuel consumption for the round trip by approximately 1500 gals.(US), or 13%.

Straight line extrapolation of those findings to fit the Canadian trip distance of 662 miles assumed by Cambrian Engineering, suggests that the reduction in fuel cost that would result from the use of covers on the coal cars operating from the southeastern British Columbia mines to west coast terminals would be in the order of 29 cents per ton. Assuming both this figure and the Cambrian Engineering figures to be precisely correct, and also assuming that the fuel savings were passed on by the railway to the producers, the benefit to the producers through discontinuance of the chemical spray system and installation of a fibreglass lift-off cover system on cars operating from the southeastern B.C. mines to the west coast

would be 23 cents per ton, as shown below.

Cambrian Engineering estimated cost for cover system	40 cents/ton
Reduce by fuel savings	29 " / "
Estimated net cost for cover system	11 " / "
Saving by discontinuance of spray system	34 " / "
Net saving through conversion to covers	23 cents/ton

A similar calculation for the steel cover case is not shown because as is obvious, steel covers would remain more costly than chemical spraying despite the fuel savings.

These figures are obviously unreliable, particularly the 29 cent fuel saving derived by straight line extrapolation of the AAR simulation results. The differences that will certainly exist between the track profile, curvature and train speeds on the Canadian route and those same parameters on the route used in the AAR simulations could result in that figure being greatly in error. Nevertheless, because of the possible significant benefits to the coal producers, it is believed that the matter is worth pursuing, at least to the extent of deriving a more reliable figure for fuel savings. This could be done by carrying out comparative simulation runs of unit coal trains with covered vs uncovered gondola cars on the Canadian route.

If such simulation runs support the above rough analysis, the question of the technical feasibility of imposing a lift-off cover system on the existing unit train operation should be thoroughly reviewed with the mine operators and the railways. As was brought out in the Cambrian Engineering report, there are a number of problems associated with implementation of the lift-off cover system which if not resolved with absolute certainty, could have serious impacts on the reliability of the overall operation. Although solutions for those problems were put forth in the report, it is possible that because in that analysis the chemical spray system was found to be the least costly, some aspects of the lift-off cover system were not given sufficient consideration by the mine operators and the railways. Also, other cover alternatives might be found to be worth exploring.

It is worth noting here that extrapolation of the fuel savings found from the AAR simulations is likely to produce a more reliable result in the case of the route to Thunder Bay than in the case of the route to the west coast, as was done above. This is because track profile, curvature and train speeds on the Thunder Bay route are likely to more closely resemble those on "the fairly level" route used in the AAR simulations than those on the route to the west coast. However, inasmuch as cover costs per ton of coal shipped on the Thunder Bay route were not developed in the Cambrian Engineering study, a calculation similar to the one shown above for the west coast route could not be made.

5.3 Slackless Drawbars

As is discussed in Section 4.4 of this report, the use of slackless drawbars in unit trains can result in major reductions to in-train forces.

Because slackless couplers are lighter than conventional couplers and draft gear, a weight saving in the order of 1,500 lb. per car would result from their use. Additionally, it is probable that the reduced in-train forces will enable re-design of the car centre sill, with further weight savings. Lighter-weight cars offer the benefit not only of reduced initial cost, but also an ability to carry more lading without exceeding the maximum gross weight limit of 263,000 lb., thereby increasing productivity. Thus, the use of slackless drawbars could result in a reduction in coal (and other bulk commodity) unit train operating costs, but more information is needed to verify that premise.

One of the important pieces of information needed is a reliable estimate of the reduction in car weight that might actually be achieved. To make such an estimate, an estimate of the reduction in the in-train forces that is likely to be achieved would be needed.

Savings through lower car purchase costs and increased carrying capacity of the cars might be offset, to at least some extent, by higher car repair costs, because of having to handle through the car maintenance facility, a complete block of five or ten cars rather than only the single bad-ordered

car. Additionally, since five or ten cars would be out of service during the repairs, instead of only the bad-ordered car, it might be necessary to purchase additional cars for spares with a consequent increase in car ownership costs. A reliable estimate of those cost increases, if any, is required.

If these pieces of information were available, a more accurate evaluation of the potential of the slackless drawbar unit train to reduce railway operating costs would be possible.

6. RECOMMENDATIONS

It is recommended that the following work be undertaken directed to exploring the potential for reductions in the cost of rail transportation of coal.

1. Covers on Coal Cars

a) Conduct simulation runs of typical Canadian unit train consists on the routes between the Western Canada coal mining area and both a west coast ocean terminal and the Thunder Bay terminal, with the purpose of ascertaining the approximate fuel saving that would result from the use of cars with covers compared to cars without covers.

b) If the simulation runs with covers indicate the likelihood of sufficient fuel savings to justify the use of covers, ascertain, through discussion with the mine operators and the railways, whether it is believed a lift-off cover system either similar to or different from that proposed in the Cambrian Engineering report is a practicable method for controlling coal dust blow-off.

2. Slackless Drawbars

Develop the following estimates:

a) Reduction in weight and purchase cost that would likely be possible for:

(i) a coal car that is to be connected to the two adjacent cars with slackless drawbars;

(ii) a coal car that is to be connected to the adjacent car at one end with a slackless drawbar and to the adjacent car at the other end with a conventional coupler and draft gear.

as compared, in each case, with a car that is connected to the adjacent car at each end with a conventional coupler and draft gear.

b) Increase in costs (if any) that would result from the operation of blocks of slackless drawbar connected cars in a train, such costs being attributable to:

(i) additional car maintenance costs
(ii) additional car ownership costs

Two estimates should be made; one for the case of 5-car blocks and one for the case of 10-car blocks.

3. High Productivity Trains

a) Ascertain, through discussion with the Association of American Railroads and other involved parties, the present status of, and future developments for, the bulk commodity train concepts which resulted from the High Productivity Integral Train (HPIT) program.

b) Ascertain, through discussion with National Steel Car of Hamilton, Ontario, and other involved parties, the present status of the "High Efficiency Coal Car for Unit Train Service" proposed by National Steel Car in their May 1987 report[30].

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